THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

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Chronicle and Comment

September, 1926, Handbook Mailed

THE September, 1926, issue of the S. A. E. HANDBOOK, the second issue in the bound form, was mailed to the members during the last 2 weeks of September. Members not receiving copies should advise the Society's office in order that lost copies may be traced.

Copy of Transactions Wanted

THE Detroit Public Library wishes to secure a copy of Part 1 of the 1924 TRANSACTIONS. No copies of this Part are available at the office of the Society, the supply having been exhausted almost as soon as the volume made its appearance last fall. Should any member have a copy of this Part of the TRANSACTIONS which he does not care to keep, it will be appreciated if he will write either to E. W. Chapin, chief of the technology department, Detroit Public Library, or to the office of the Society.

Producers Talk Shop

"OF, by and for production men," the slogan of the recent meeting in Chicago describes concisely the spirit of a very successful gathering that represented an advance step in the Society's production activities. That these activities are coming to mean more throughout the industry is evidenced by the fact that numerous automotive plants made special arrangements to allow their manufacturing executives and production men generally to attend the technical sessions and factory visits that were included in the program.

A number of the Production Meeting papers appear in this issue of THE JOURNAL; an illustrated news account of the meeting will be found on p. 325.

Coming Events

THE next important event on the Society's calendar of national meetings is the Transportation and Service Meeting that will be held in Boston in November. Interest in the topics that will be discussed at the Transportation Meeting has increased very markedly from year to year and it is anticipated that, under the able guidance of J. F. Winchester and his committees, the Boston meeting will set a new record. Interesting details concerning the plans for this meeting will be found in this issue of THE JOURNAL, in the November issue, and in editions of the *Meetings Bulletin* that will appear in due course.

The Tractor Meeting scheduled for early in December will be the last national meeting of the calendar year.

Sections Promise Well

THE past month has witnessed the opening of Sections work in a number of localities; practically all the Sections will be in full swing during October. Officers and committeemen have been busily engaged in formulating plans and completing arrangements that promise well for the success of the present season. The Society's officers and Council extend their best wishes for a very profitable year.

New Haven Machine-Tool Exhibit

THE New Haven exhibit of the machine-tool builders that was held at the Mason Laboratory of Yale University, in September, was in step with the progress that has been made by the machine-tool industry since the exhibit held a year ago. In general, the nature of the exhibits was the same as last year but these embodied improvements in machine-tool design that have been devoloped since that time. Practically all of the exhibits were in actual operation and were of educational interest to approximately 15,000 visitors. The question as to whether to continue the exhibit annually was discussed, with the result that it was decided to do so as heretofore; the exhibit for 1927 to be held at Sheffield Engineering School on Sept. 6 to 9, 1927.

More Attractive Publicity

WHEN members write to headquarters to comment favorably upon the contents and composition of Sections' publicity material, as has been the case in connection with the latest Metropolitan Section Booster, we become more than ever convinced that it pays the officers of a given Section to devote considerable time and thought to this important factor of sections work. Fundamentally, a Junior Journal, a Booster or other publicity medium is an instrument for selling a particular event or series of events; it should be considered as such. Consequently, for the best effect, the editor of this medium must have his "prospects"; then, he must have something to sell; and, finally, he must present his wares in an attractive, instructive and available form.

We have numerous examples of this from various Sections. Our Pennsylvania Section recently released a

prospectus covering the year's events that would attract the notice and interest of any automotive engineer. Other Sections are to be commended for their efforts in this direction, but it is urged that all who are desirous of promoting the interests of our local units devote special thought to progressive advertising.

International Standards Association

IN the matter of the proposal to organize an International Standards Association, as mentioned in the September issue of THE JOURNAL, various meetings were held last month in New York City, including a session of the Committee on Foreign Cooperation, of which Dr. G. K. Burgess, director of the Bureau of Standards, is chairman. The subject was also discussed at some length at the September meeting of the American Engineering Standards Committee. A special conference of interested members of this Society was held. As a result of this and the discussion had at sessions of other organizations, the following was outlined as the attitude of the Society:

> The principle of international cooperation and unification in engineering standardization is approved.
>
> The formation of some organization that will provide proper machinery for collecting and disseminating information and promoting cooperation among the national standardizing bodies in various countries is approved.
>
> The adoption of international engineering standards should be approached most carefully and the organization above proposed should be capable of conversion into an international engineering standardizing body if, when and to the extent experience shows that such a function is desirable.
>
> American participation in the organization referred to should be through the American Engineering Standards Committee.
>
> If or when the adoption of engineering standards as international standards is undertaken, the procedure should be substantially the same as in the adoption of national standards and the machinery therefor should be provided through the American Engineering Standards Committee as it at present exists or as it may exist if and when merged with any present existing body organized for international technical cooperation.

It is understood that the national standardizing organizations in various countries favor the establishing of an international standards association. The fundamental idea underlying the proposed movement is the federating of the accredited national organizations for cooperating in standardization work. Obviously many complications are involved in any such international procedure.

Veal Appointed Research Manager

C. B. VEAL has become the Manager of the Research Department of the Society. This announcement is made with pleasure as well as gratification. Mr. Veal is well known to the members and has been one of the most active, faithful and helpful workers in the Society's cause since he became a member in 1912. He was graduated as a mechanical engineer at Purdue University. After service at that institution in various capacities, including instructing in machine and internal-combuston-engine design, developing a course in automatic engine design, proposing and putting into operation an automobile testing plant, and administering a course in automobile and motor-truck design, he became professor of machine design in charge of the design department and of the testing of automobiles and engines and parts therefor and of heat-treated metals. He was also retained as engineer by builders of passenger cars, motor-trucks and farm equipment machinery. He has made many studies in the field of agriculture and of special machinery and production engineering work.

During the World War Mr. Veal became assistant inspection engineer of the Curtiss Aeroplane & Motor Co. Since 1919 he has practised consulting engineering in association with Past-President Manly.

Mr. Veal was a member of the Research Division of the Standards Committee for 3 years while that Division was in existence. He served as a member of the Sections Committee for 3 years. Having participated in the work of the Standards Committee, in the Motor-Truck Division particularly in recent years, and having been a frequent advisor in Society matters relating to its fundamental welfare in connection with the grading of applicants for membership, Mr. Veal is thoroughly familiar with the activities in which the members are particularly interested. He has been a keen student of and peculiarly effective in the organizing and maintenance of Sections of the Society, than which there is nothing more important in our procedure.

The Research Committee and the Research Department have resumed active work for the season. The Research Committee will hold a meeting in New York on Oct. 4. A session of the Cooperative Fuel-Research Steering Committee will be held on the same day at the headquarters of the American Petroleum Institute. The main projects now being conducted under the auspices of the Research Committee are Contaminated Crankcase-Oil Investigation (largely completed), Cooperative Fuel-Research, Headlighting, Highway Research, Riding-Qualities, and Gear Research.

VOLATILITY TESTS FOR AUTOMOBILE FUELS

IN Fig. 1 of the paper with the above title which was presented by T. S. Sligh, Jr., at the Semi-Annual Meeting and printed on p. 153 of the August, 1926, issue of THE JOURNAL, the lowest curve was incorrectly marked due to an error in the manuscript. This curve gives the vapor-pressure ratio of heptane to decane and not hexane to decane as shown and is plotted against the scale of ordinates at the right. The decane vapor-pressures used in the preparation of this curve are those for an isomeric decane having a normal boiling-point of 159.1 deg. cent. (318.4 deg. fahr.).

"OF, BY AND FOR PRODUCTION MEN"

Recent Chicago Conclave Enjoyed by Representative Group of Producers

Approximately 400 automotive production men found sufficient material of interest to them in the events of the Chicago Production Meeting, Sept. 21 to 23, to warrant their leaving important duties at their plants in order that they might participate with their colleagues in the noteworthy features that had been provided by V. P. Rumely and the members of his committees. Conveyors, gear production, inspection, and machine tools were among the topics that were discussed and rediscussed in detail. The stag carnival, principal social attraction of the meeting, registered a distinct hit.

Many of the members took advantage of the opportunities afforded for factory inspection visits at the plants of the Nash Motors Co. at Kenosha, Wis., the International Harvester Co. and the Yellow Truck & Coach Mfg. Co. The many courtesies extended by those in charge of these plants were appreciated by the visiting production men.

In the list of attractions in Chicago during the Production Meeting were the entertainment and the technical events of the American Society for Steel Treating with which the Society of Automotive Engineers exchanged courtesies. The National Steel and Machine Tool Exposition of the American Society for Steel Treating was undoubtedly one of the greatest expositions of its kind ever held.

A number of Production Meeting papers are printed in full in this issue of THE JOURNAL; others will follow. An illustrated news account of the meeting will be found on the following pages.

CONVEYOR SYSTEMS AND THEIR BENEFITS

Speakers Tell of Handling Methods That Save Space and Labor and Speed Production

Production is speeded-up enormously in the plants of the automotive industry and savings in labor cost are effected by mechanical handling systems that sometimes pay for the entire cost of the installations in a few months, the members of the Society who attended the first session of the Production Meeting in Chicago on Sept. 21 were told by the two speakers. Two papers were delivered, each illustrated by a score or more lantern slides of photographs and diagrams of power-driven conveyor systems that have been installed in automobile, body, engine, and axle plants and engine-block foundries. The general subject of transportation by conveyor was dealt with broadly in a joint paper by Paul Phelps and N. H. Preble, of the Mechanical Handling Systems, Inc., which was presented by Mr. Preble. In the second paper, prepared and delivered by Clarence A. Brock, of the Miller-Hurst Corporation, various conveyor systems used in the automotive industry were described more specifically.

Eugene Bouton, of the Chandler Motor Car Co., as chairman, opened the meeting with the remark that the thought uppermost in connection with industrial transportation problems has been the element of manual-labor saving which already has effected great economies, but the broad principle of conveyors seems to be imperfectly understood and insufficiently applied. The possibilities of reducing cost through efficient handling of material are far greater, he said, than in any other branch of indirect labor, and as material handling constitutes a large part of the process of manufacturing any given part, many production men believe as much attention should be devoted to coordinating this with the production flow as to machine-tools and their elements.

CASTERS PRESENT A DIFFICULT PROBLEM

Both papers were listened to attentively. They appear in full in this issue of THE JOURNAL. Following their delivery, Chairman Bouton opened the discussion by asking a number of questions himself. He inquired of Mr. Preble what his experience had been with the caster situation and the oiling of casters on body trucks, to which the latter replied that this is almost a universal bugbear, particularly in body plants in which the bodies pass over a very long run, and that he does not know any solution of it. The loss that can result from failure of a caster is not the cost of replacement but the delay in production that may occur. Various methods of oiling have been tried, such as running the casters in depressed channels through an oil bath, and placing oiling tubes on each side of the casters to squirt oil on them when they tripped a trigger. The first method allowed too much oil to drip on the floor and the other, he said, is a rather tricky method.

Another query put by Chairman Bouton was what radius is permitted in a vertical plane in the case of the monorail conveyor. Mr. Preble said that the smaller the radius is the sharper is the bending of the chain and the greater the component on the carrying trolley due to tension in the chain; therefore, in general, the lighter the chain pull the more sharply the chain can be bent. In one installation of a 200-ft. chain, the radius of curvature in the vertical plane was only 4 ft. Where a sharp bend is required, the chain must be of very flexible type and a forged chain is probably the most suitable. As a rule, he prefers a radius of not less than 15 ft.

CHAINS CAN RUN VERTICALLY

To J. C. Slonneger, of the International Harvester Co., he replied that, so far as the conveyor chain and trolley are concerned, the chain can be run at right angles from the horizontal but the angularity will be determined in some cases by interference of the corners of large pieces with the chain.

He said he does not know of any best way to deal with accumulations of paint on the chain and the casters of trucks. If lacquer is being used the chain could be passed through a solvent bath, or in case of paint it can be run through a burn-off oven. Many lines in body shops run through Duco and varnish rooms and no provision is made for cleaning them.

Mr. Brock said that one company prefers to use four power units to drive four short lines while another prefers

Eugene Bouton

Clarence A. Brock

Paul Phelps

N. H. Preble

THE CHAIRMAN OF THE CONVEYOR SESSION AND THE THREE AUTHORS OF THE TWO PAPERS PRESENTED

the economy of driving two conveyors in opposite directions with one unit and synchronizing them.

Speaking of driving speed, V. P. Rumely, of the Hudson Motor Car Co., said that at one time his company thought a speed of 3 ft. per min. for a car-assembling track, with an average of two men working around a chassis or assembled car, was about right but after experimenting found that the speed could be increased to 12 or 15 ft. and the number of men to six or eight without affecting the quality of the work. Where formerly 350 cars were got off the line in 9 hr., they were finally able to get 1180 cars out, which shows the possibility of securing unanticipated results from conveyor installations.

WHAT HAPPENS IF GEAR MEN DISAGREE?

Differing Ideas about a Topic of Vital Interest Discussed at Production Meeting

One of the distinguished speakers at the Gear Production Session, which convened in the grand ballroom of the Hotel Sherman, Chicago, on the afternoon of Tuesday, Sept. 21, said that gear men seem to live on disagreements. The truth of his statement was evidenced and illustrated by the nature and the volume of discussion that followed the presentation of each of the two papers that constituted the program for that session.

Robert S. Drummond, of the Gear Grinding Machine Co., chairman of the session, called attention in his opening remarks to the widespread interest in gears, because everyone who rides in cars or who produces cars is concerned with the subject of gearing, both as to its life and its quietness of operation. Although much improvement has been made in various phases of the gear problem, a complete solution has not yet been reached, he said, and anyone bringing to production engineers further knowledge on this subject is most welcome.

A FRANK INTERCHANGE OF IDEAS

Walter G. Hildorf, of the Reo Motor Car Co., presented an interesting paper on Gear Steels and the Production of Automobile Gears, that had been prepared by the speaker and John Bethune of the same company. Mr. Bethune because of a serious accident to himself some weeks ago was unfortunately unable to attend the meeting, but A. A. Nichols from the gear department of the Reo Motor Car Co. was present to participate in the discussion.

Stating that the production of satisfactory gears is one of the most serious problems confronting the automobile builder today and urging the need for a frank interchange of ideas as the best way to hasten the time when a more satisfactory system of gearing will be developed, Mr. Hildorf gave an outline of his company's practice in making gears. In presenting the paper, which was interestingly illustrated by slides, he discussed gear steels and their heat-treatment, told about experiments that had been conducted with gears, gave the results of recent research work on steel, and spoke briefly about his ideas for future investigations. The paper appears elsewhere in this issue of THE JOURNAL.

4-IN. VERSUS 3-IN. CUTTERS

The respective merits of 3-in. and 4-in. cutters furnished the first topic for discussion, at the conclusion of Mr. Hildorf's presentation. A. A. Nichols preferred the 3-in. cutter, because the larger cutter, he said, was more likely to contain an imperfection on account of its larger diameter and larger number of teeth. Eugene Bouton, of the Chandler Motor Car Co., who raised the question, advocated the use of 4-in. cutters, maintaining that by their use production is increased approximately 22 per cent. O. C. Kavle, of Manufacturers' Consulting Engineers, stated that the results obtained by the use of the cutter with the larger diameter would be similar to the results obtained by increasing the feed; that is, if the smaller cutter were used and the feed increased, the production would be the same as with the larger cutter. Mr. Bouton disagreed with this view and drew on the blackboard a diagram to illustrate his contention regarding the superior merits of the 4-in. cutter.

In answer to a question about the best method of checking or inspecting Fellows cutters, Mr. Hildorf replied that it is easier and just as effective not to check the cutter at all but to check the gear itself.

A DISCUSSION OF GEAR NOISE

Mr. Hildorf had in his paper voiced the belief that cyanide-treated gears will wear much better, will be somewhat noisier than the electric-furnace treated gears and will have a different sound. Asked for the basis for this statement, he replied that the results obtained directly from experiments were responsible for this opinion, but added that the experiments had been conducted mainly with two kinds of steel and he would therefore not want to make a definite decision regarding noise in this connection except with the two steels used.

E. F. Davis, of the Warner Gear Co., said that he had recently studied this subject without finding any difference in sound between the cyanide-treated gears and the electric-furnace-treated gears.

A. H. Frauenthal, of the Chandler Motor Car Co., stated that, as a result of certain experiments, he had found that the cyanided gear has an unquestionably different sound from the electric-furnace-treated gear. Speaking of the cyanide-treated gear, he said that as to its being noisier he has found that when gears are cut with rather a rough finish, the cyanide-treated gear would be much noisier than the electric-furnace-treated gear, but that if a gear is given a good finish, is burnished and then cyanided, it will be very

little, if any, noisier than the electric-furnace-treated gear.

C. A. Lampard, of the Yale & Towne Mfg. Co., spoke of the gear problems involved in connection with electric storage-battery trucks, with especial reference to the matter of getting quiet gears. His company uses, he said, a cyanided gear of S.A.E. No. 3140 steel. The practice is to normalize the gears, to machine them as closely as possible, reheating to 1550 deg. fahr., and cyaniding. The cyanide has been heated to 1550 deg. fahr., and the gears are heated in an electric furnace to the same temperature. Mr. Lampard believes that the critical point in the whole treatment is involved in this matter of having the cyanide and the furnace at exactly the same temperature. The gears, he continued, are transformed from the electric furnace into cyanide pots for 30 min.; after being removed from the cyanide pots they are allowed to drain off. Noisy gears, he stated, would result if no further treatment were given, but after the gears are drained off and cooled down to room temperature they are boiled in water for about 2 hr., are rinsed off, put back into the furnace, reheated, and quenched; afterward they receive a very light sand-blast. Mr. Lampard claimed that a cleaner and quieter gear is obtained by this method and that less trouble from distortion is experienced.

Other Questions Discussed

Asked about the best grain structure for smooth machining of alloy-steel containing 0.50 per cent of carbon, Mr. Hildorf replied that sufficient data are not available to make anyone's answer at this time anything more than an expression of opinion.

What steel is best for high-duty gears transmitting heavy power and how do carburized gears compare with high carbon gears in this respect, was the next question to receive Mr. Hildorf's attention. He said that his company uses carburized, rather than oil-hardened, steel in the gears for its truck transmission, to prevent the danger of flaking.

A member asked whether Mr. Hildorf considered tensile strength more important than impact in differential gears and pinions, and Mr. Hildorf replied that he feels no concern regarding tensile strength and other regular physical properties, as the steel men take care of these properties satisfactorily; he feels, however, that much investigation is needed with regard to fatigue and impact.

Interest was expressed in the matter of grinding hardened gear teeth, and discussion centered around the question as to whether the tooth surface is as hard as before grinding. Chairman Drummond summed up the points brought out in this portion of the discussion by stating that the determining factors are the degree and depth of the hardness and the amount ground off.

Grain size of steel received some consideration. Mr. Hildorf stated that, although grain size can be changed temporarily by quenching, treating and forging, yet the physical properties of the steel always bear a definite relation to the grain size which he termed "an inherited proposition from the steel mill."

Another member brought up the question of the cause of noise in timing-gears when the gears themselves, after inspection and re-inspection, have been found to be all right. Mr. Hildorf pointed out that the trouble in many cases would lie in the mounting of the gears, but expressed the opinion that no gear man would want to undertake the making and mounting of two gears, not covering them with a case and not drowning them in oil, yet guaranteeing a quiet job. The reason for this condition, he asserted, is traceable to the fact that gear research has not yet revealed the fundamental laws upon which sound practice must be based, and in this connection he urged the need for properly-directed research.

A member asked whether less warpage was experienced on carburized 2315 gears when quenching from 1460 deg. fahr. than from about 100 deg. fahr. lower. Mr. Hildorf replied that as good results can be obtained at 1460 deg. fahr. as at lower temperatures, provided that the right heating rate is determined.

Asked what method of making the ring-gear blanks has been found most satisfactory to give uniform tooth structure, the speaker expressed an opinion favorable to the use of upset forgings.

A. B. Bolender, of the Warner Gear Co., provoked some interesting discussion by asking what results would be obtained if Fellows cutters were made about 0.060 in. over standard in pitch diameter; several opinions were expressed but no conclusive agreement was reached.

Gear Problems of Today

F. G. Eberhardt, of Gould & Eberhardt, after being introduced as the second speaker of the session, presented a paper, entitled Automobile Gear Production, that had been prepared by Charles L. Cameron, of Gould & Eberhardt. This paper covered in a comprehensive way the cutting by the hob generating method of automobile transmission gears, helical timing-gears, flywheels, starter ring gears, steering worms, steering wormwheels, camshafts, pump spiral gears, spline shafts, and miscellaneous work. Besides giving descriptions of methods and equipment, the speaker showed numerous slides which illustrated complete examples of production. The paper will doubtless appear in an early issue of The Journal.

Mr. Eberhardt Answers Questions

At the conclusion of Mr. Eberhardt's presentation, several questions were asked regarding points raised in the paper. Relative to the most satisfactory angle hook for cutting face of roughing hobs, the speaker recommended an 8 or 10-deg. angle. Asked what angle range his special machines have for helical gears, he stated that they can be arranged anywhere up to about 30 deg. for either right or left-hand gears.

R. S. Drummond

Charles L. Cameron

John Bethune

Walter G. Hildorf

The Gear Production Session Chairman and His Trio of Authors

A request that Mr. Eberhardt name the advantages that the gear hobbing machine has over the Fellows gear cutting machine for finishing transmission gears brought forth the statement that there are some gears that nobody attempts to cut except on a Fellows machine, such gears being so close to another gear that they can be reached only by a Fellows cutter; in all other cases, said Mr. Eberhardt, the customer must use his own discretion.

Another question raised the point as to whether on flywheel ring gears it is good practice to turn the outside diameter with topping hob. James Craig, of Gould & Eberhardt, stated that, although this practice is followed in some plants for the sake of cheapness, he is opposed to it. Mr. Kavle, however, expressed his opinion that it is the only method to get a gear true.

The large and appreciative audience that attended the Gear Production Session received the two papers with much interest and followed the discussion with keen enthusiasm.

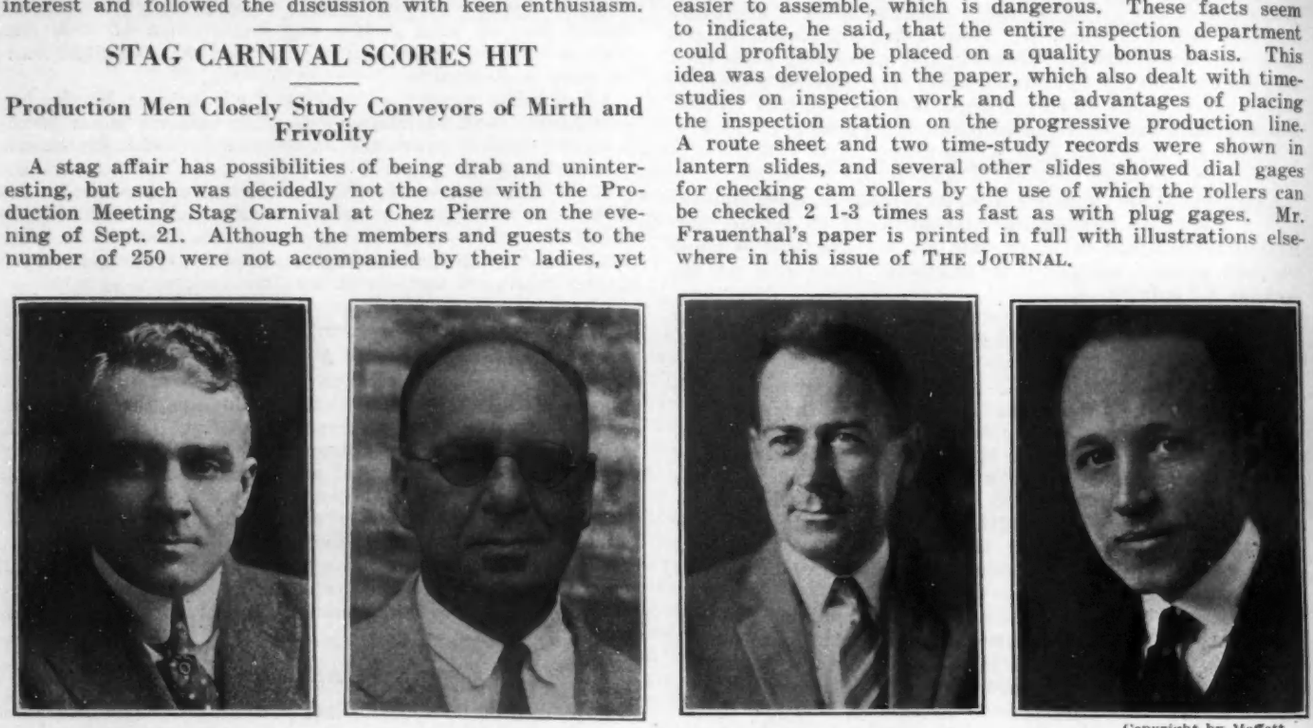
STAG CARNIVAL SCORES HIT

Production Men Closely Study Conveyors of Mirth and Frivolity

A stag affair has possibilities of being drab and uninteresting, but such was decidedly not the case with the Production Meeting Stag Carnival at Chez Pierre on the evening of Sept. 21. Although the members and guests to the number of 250 were not accompanied by their ladies, yet the fascination of femininity was amply supplied by a host of nimble fairies who did the entertaining.

Four hours of enjoyment were ushered in by a delectable dinner during which the orchestra and entertainers were accompanied by lusty blasts from the tin horns of the paper-hatted revelers. From the Powder-Puff number to the startling scene from Artists and Models, the evening's revue of music and dancing was staged in a faultlessly artistic style that was particularly pleasing and in good taste.

A noteworthy feature, not on the program, was the appearance, through the courtesy of Paul Geyser, of Neal Begley, formerly of the Metropolitan Opera Co. and now of the Yellow Truck & Coach Mfg. Co. Mr. Begley rendered a well-chosen group of the more popular opera selections and was generously applauded. His brilliant tenor voice added a decidedly pleasing touch.



Taliaferro Milton C. A. Peirce Lee W. Oldfield W. J. Buettner

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THE LOCAL RECEPTION COMMITTEE'S CHAIRMAN AND THREE MEMBERS WHO ASSISTED HIM IN ENTERTAINING THE VISITING MEMBERS

INSPECTION METHODS AND DEVICES

Bonus System for Inspectors—New Inspection Tool Put in Industry's Hands

Inspection to guard against imperfections and assure accuracy of machine work was emphasized as one of the most important phases of production at the Wednesday forenoon session of the Production Meeting. In the absence of L. Clayton Hill, who was taken ill at the station in Detroit as he was about to leave for the meeting, John Younger presided as chairman and in his introductory remarks observed that inspection is one of the most important problems facing any industry today, and that while quality of a product cannot be written down and is most elusive, the inspector is safeguarding it all the time and is practically guaranteeing the product.

In the principal paper of the session A. H. Frauenthal, chief inspector of the Chandler Motor Car Co., said that in spite of every reasonable precaution quality will slip sometimes and errors will be made that will not be detected until the parts are issued for assembling. Frequently the inaccuracy first becomes manifest by increased difficulty in assembling, which draws immediate attention to the basic trouble, but on the other hand errors may make the parts easier to assemble, which is dangerous. These facts seem to indicate, he said, that the entire inspection department could profitably be placed on a quality bonus basis. This idea was developed in the paper, which also dealt with time-studies on inspection work and the advantages of placing the inspection station on the progressive production line. A route sheet and two time-study records were shown in lantern slides, and several other slides showed dial gages for checking cam rollers by the use of which the rollers can be checked 2 1-3 times as fast as with plug gages. Mr. Frauenthal's paper is printed in full with illustrations elsewhere in this issue of THE JOURNAL.

SOME NEW INSPECTION DEVICES SHOWN

Among several new inspection devices that were described in a symposium on the subject, one developed at the plant of the Packard Motor Car Co. operates on a principle not heretofore used in the industry and seems to offer wide possibilities of application. As described by C. S. Stark, of that company, and illustrated with a diagrammatic drawing, it makes use of the elementary principles of radio amplification and indicates on a dial the perfection of finish on a metal surface by the action of a beam of light from a microscopic lamp reflected from the finished surface upon an alkali-metal photo-electric cell, such as is used for the telegraphic transmission of pictures. This cell is connected in an amplifying circuit to a milliammeter, which gives very accurately the degree of polish on the surface of the sample.

A. R. Fors, of the Continental Motors Corporation, showed and described a fixture and templets for checking block cylinder-and-crankcase castings and indicating the metal to be removed in all the machining operations; also a special gage for checking the depth of the combustion-chambers in cylinder-head castings.

Some of the operations on Knight sleeve-valves and the inspection methods that ensure accuracy of bore, thickness of walls and size of ports to limits of plus or minus 0.002 in.

J. B. Scott

P. W. Rhame

TWO OTHER AUTHORS OF INSPECTION SESSION PAPERS

in a length of nearly 10 in., were shown and described by J. B. Scott, of the Yellow Sleeve Valve Engine Works.

How accuracy of the small worms and gears used in speedometers and the quietness of operation of the instruments are checked was told by P. W. Rhame, of the A. C. Spark Plug Co., whose paper was illustrated with 10 lantern slides. An innovation in the operation of cutting the small gears and worms for speedometers in which all production men should be interested, Mr. Rhame said, is the filtering of the cutting compound through an oil-filter on the machine to remove small chips from the compound and collets to maintain accurate concentricity of the parts. This filtering, incidentally, has materially reduced the machine wear.

The last three of the foregoing papers in this symposium appear elsewhere in this issue of THE JOURNAL.

JUDGMENT BY SOUND AND SIGHT ERRATIC

The most important part of our gaging system is the human element, according to R. R. Todd, of the Oakland Motor Car Co., who spoke of the difficulty of securing uniformity of inspection for noise and body-finish color and blemishes, where reliance must be placed upon the hearing and vision of the inspectors. The greatest difficulty is in securing a man with a keen enough sense of hearing to enable him to standardize to a point where a uniform product can be maintained. Only about 1 man in 500 has such a capability and even such a man has his "off" days; his standard is sometimes affected by the way he gets out of bed in the morning, said Mr. Todd, with the result that he rejects many axles, transmissions or engines that are commercially satisfactory, or some outside cause may affect his hearing so that he will pass units that should be rejected. The development of an instrument that will indicate or register noise in a practical way will be one of the greatest assets to modern mass production. In visual inspection, also, men must be picked who are above the average in ability and have an even disposition, as personal judgment must be uniform from day to day, and temperamental men cannot be educated to this.

RATIOS AND AVERAGES USELESS IN INSPECTION

Discussion on Mr. Frauenthal's paper, participated in by him and Chairman Younger; B. H. Gilpin, of the H. H. Franklin Mfg. Co.; Eugene Bouton, of the Chandler Motor Car Co.; P. W. Rhame; and Earl A. Taylor, of the Yellow Sleeve Valve Engine Works, reflected the belief that inspection cannot be worked out on a basis of percentage to the number of machine operators nor on percentage of cost of the items that go through the machine-shop, the variables being too numerous. When the operating force is reduced the inspection should be increased because there is more inspecting to do and it is harder. The question also hinges on what is meant by or included in inspection and how large a percentage of the entire car is manufactured in the plant.

INSPECTION TRIP OF UNUSUAL INTEREST

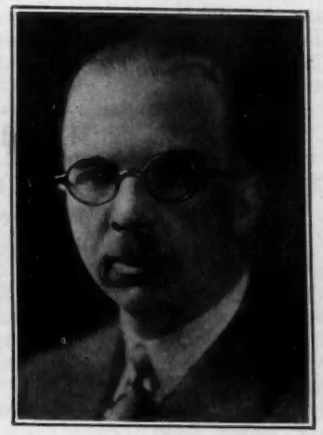
Visit to Kenosha Plant of Nash Motors Co. Attracts Large Group

Directly after the close of the Inspection Session, at noon on Sept. 22, about 100 members and guests started on the afternoon inspection trip to the Nash Motor Co. factory. A special train carried them over the North Shore route, and during the trip lunch was served.

A. H. Frauenthal

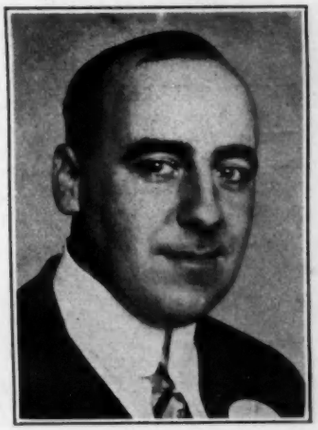
C. S. Stark

R. R. Todd

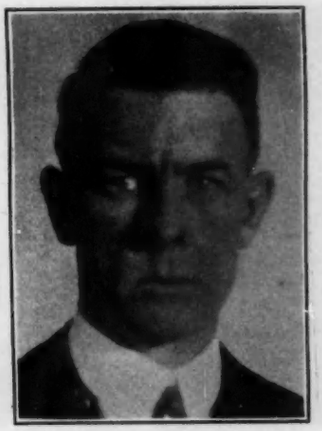


A. R. Fors

FOUR AUTHORS OF PAPERS PRESENTED AT THE INSPECTION SESSION



R. E. Wilson



F. G. Whittington

A PAIR OF MEMBERS OF THE LOCAL RECEPTION COMMITTEE

C. W. Nash personally welcomed the group, upon their arrival at the factory. He spoke briefly of the advancement of the automobile in the past years and showed how it has been due almost entirely to the untiring efforts of the automotive engineers. Standardization of methods with great trends toward still more scientific and accurate work he predicted for the future of the industry, expressing his belief that progress will be made through refinement of product rather than through new and radical ideas.

After listening to Mr. Nash's splendid talk, the party was divided up into small groups in order that they could follow production operations throughout the plant more thoroughly, and the inspection trip started. The methods of heat-treating metals in their course of production were especially noteworthy and the accurate quality-control in electric-furnace work was of interest to all. The forge shop attracted many, for the methods of handling these products are always of interest.

In the foundry the conveyor system used for the engine castings represented one of the most recent developments in modern foundry production processes, where quantity production is desired in the minimum of space. The engine castings were then followed through the succeeding steps and inspections down through the assembly line to the test stands, and many interesting steps in production processes were well illustrated.

The general chassis assembly lines show the ultimate results of the entire group of production units, for here is the point at which an even flow of all materials is essential to maintain the best possible continuity of production.

After the enjoyable inspection visit through the factory, the party boarded the special train for Chicago and, with the aid of a well-served dinner on the return trip, arrived back feeling that it had been a most interesting and instructive trip.

MACHINE-TOOLS AROUSE DISCUSSION

Talk Centers on Honing, Diamond Cutting-Tools, and How To Improve Machines

Much discussion followed the presentation of the two papers at the closing session of the Production Meeting on the forenoon of Thursday, Sept. 23. The desire of the builders of machine-tools on the one hand and the users of their product on the other hand to cooperate, to learn as much as possible from one another and to improve both machines and methods was evident. No disposition to criticize developed; on the contrary, suggestions made by one group were freely commended by the other, which augurs well for the advancement desired by all.

In the first paper, Fitting the Machine-Tool to the Job, which is printed elsewhere in this issue, O. C. Kavle showed lantern slides of about a dozen machine-tools especially designed or adapted from standard tools for performing specific operations on automobile parts and explained their operation whereby handling time is saved, scrap-loss is reduced, production speeded-up, and quality of the product improved.

How Machines Can Be Improved

The second paper, What Goes Wrong with Machine-Tools, by E. R. Stoddard, of the Studebaker Corporation of America, was delivered by E. A. Longgood, plant engineer of the same company. In it the author incorporated some recommendations for preventing failure of the machines, and these obviously were regarded by the hearers as the most important part of the paper.

To show how serious and costly the failure of a machine in a production line may be, it was pointed out that, on a schedule of 400 cars a day and a net profit of $100 per car, the direct cash loss of a stoppage amounts to about $4,000 per hr. if the bank of parts in reserve is not sufficient to tide over the interim in which repairs are made. From reports turned in by men in the South Bend plant who have had charge of equipment maintenance in the last 7 years, the main causes of failure in the order of their importance are (*a*) lack of lubrication, (*b*) overloading and carelessness and (*c*) poor design or construction of machine-tools.

As preventives of (*a*), machine-tool builders were recommended to provide positive force-feed lubrication to all high-speed moving parts, manifold oilers with sight-feed, copper tubes from oil-holes to one or more central oil reservoirs, liberal-size self-oiling loose pulleys capable of running 24 hr. without reoiling, and traps in all oilers to collect chips and other foreign substances.

Failures from cause (*b*) can be reduced greatly by foremen and operators making sure that all work is secure in the jig before machining begins, keeping machines free from chips, keeping cutting tools sharp at all times, removing from machines castings or forgings that are too hard or have an excessive amount of stock, keeping machines well lubricated, and keeping loose tools and other objects that might fall into working parts off the machine.

Suggestions to machine-tool designers were to provide interlocking handles or clutches for moving parts and shear-pins to prevent overloading, design the machine so it will free itself easily from cuttings or work and keep chips away from lead-screws and gears, and, where standard machines are furnished for a specific operation, ship all moving parts not required for the operation in a separate container with full instructions for installing and using them in case they may be wanted for some other operation.

Joint responsibility for keeping machine-tools running continuously rests, in the author's opinion, upon the designer, the builder, the department foreman, and the operator using the particular machine.

Special Versus Combination Tools

When Chairman W. G. Careins opened the discussion, A. H. Lyons, of the Ingersoll Milling Machine Co., suggested

L. F. Maurer

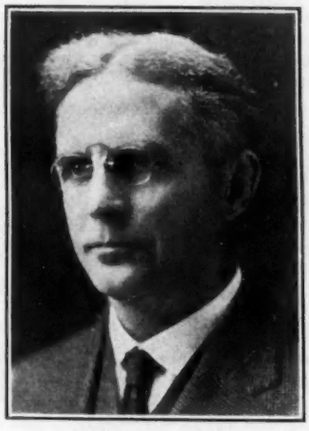
P. J. Moohan

Joseph Lannen

Louis Ruthenburg

Four of the Members of the Committee Responsible for the Success of the Production Meeting

W. G. Careins



Oscar C. Kavle

THE CHAIRMAN (AT THE LEFT) OF THE MACHINE-TOOL SESSION AND (AT THE RIGHT) THE AUTHOR OF ONE OF THE PAPERS

that it might be worthwhile to consider the advantages of simple tools for different operations in a production line, as for cylinders or crankcases, as against tools to take care of a great number of operations, the piece passing from machine to machine without leaving the conveyor. Responding, M. K. Zwolinski, of the Hudson Motor Car Co., said that this question depends upon the production quantity; it might work well in one plant and not in another.

Water-cooling the work during machine operations is rather unusual, said Mr. Careins, but in the plants of his company it had been found desirable when boring and reaming cylinders to fill the water-jackets with water, which increases the life of the tools and the quality of the work.

E. K. Morgan, of the Ingersoll Company, inquired how many find they can hone cylinders and go below the reamer marks, and Mr. Stein, of the Fairbanks-Morse Co., said his company removes about 0.002 in. and attempts to remove all reamer marks. Mr. Kavle observed that to keep a cylinder from pumping oil it is necessary to take out all marks.

The machine-tool builder is expected to furnish machines of much more attractive appearance than special tools built by the user, and for much less money, and he generally does it, asserted E. F. DuBrul, secretary of the National Machine Tool Builders Association, who commended to the builders the suggestions made by Mr. Stoddard regarding automatic lubrication, interlocking control and separate containers for parts not needed for the immediate operations. What this amounts to, he said, is transferring intelligence from the operator to the machine, which has become necessary because the demands of industry have exhausted the supply of skilled labor.

Mr. Careins brought up the question of the use of diamond cutting-tools and Mr. Kavle, in reply to questions by J. S. Chafee, of Brown & Sharpe Mfg. Co.; C. W. Emmons, of the Walker Vehicle Co., and E. A. Cousins, of the Hyatt Roller Bearing Co., spoke of the very fine work that can be done with diamond and sapphire tools and said that the work analyzes much differently under the microscope than that done with steel tools, that any desired cutting speed can be used but the feed must not be forced, that the working temperature must be kept uniform to get uniform measurements, that the diamonds will not last indefinitely but must be reground, and that there is as much difference between diamonds as between cold-rolled and tool steels.

TRIP TO INTERNATIONAL HARVESTER CO.

Society Members and Guests Enjoy Instructive Visit to Tractor Works

In spite of the doubtful weather, about 35 members and guests met at the Hotel Sherman at 1:30 p. m. and were taken to the International Harvester Tractor Works in the latest and most comfortable models of International motorcoaches.

The inspection trip began with the forge shop, and one was impressed with the apparent ease and uniformity with which all operations were performed. From the larger crankshafts and axles to the smaller pins and fittings they were turned out with a precision that only the most modern production methods can control. All preliminary heating is done in oil furnaces, and heat-treatment of the forged products is controlled in electric furnaces of continuous operation types.

The machine shop with its machining of all crankshafts proved very interesting, and in following these parts through their conveyored paths one gained many points of knowledge in the methods of handling materials and their accurate control and check for production.

The engine assembly of the conveyor type with each engine mounted on a special rotatable carriage offers great ease for quantity production, and the layout for handling each part of the assembly was most complete. After its complete assembly the engine is put on the test block for a given run-in, going then by gravity conveyor to its special place in the tractor assembly line.

The main tractor assembly line again shows how, with the use of special machines, production methods can be reduced to a few simple standard operations. Running a complete unit off at the end of the line every 5 min. under its own power tells the whole story of one great system, for every part is a standard part and handled only in standard production ways, by most carefully laid out methods.

The tractor wheel department, gear department and other points of interest were given a brief visit, as far as time would permit, but even this limited inspection helped to prove conclusively the advantages of such thorough systems.

After the factory visit was over, the waiting motorcoaches brought the party back to the hotel most comfortably in spite of a heavy rain, and one could not help agreeing that the trip had been both enjoyable and exceedingly worthwhile.

CROWD VISITS YELLOW COACH PLANT

Construction of Taxicabs, Trucks and Motorcoaches Holds Interest of Members

The fabrication of motorcoach bodies was the first item of interest observed by the group of production men who visited the plant of the Yellow Truck & Coach Mfg. Co. on the afternoon of Sept. 23, the last day of the Chicago Production Meeting. Going through the millroom, then witnessing the application of the metal and finally coming to the point where the body and the chassis were united before painting, the visitors inspected the interesting equipment and

TWO WHO HELPED MAKE THE INSPECTION VISITS A SUCCESS
Paul H. Geyser (at the Left) Was the Host of the Visitors to the Yellow Truck & Coach Mfg. Co. Plant and O. W. Young (at the Right) Was Chairman of the Factory Inspection Committee

processes of a plant capable of producing 10 complete coaches per day. Many types of body were seen in various stages of completion, and an opportunity was afforded to study the chassis assembly; several gasoline-electric jobs were among the vehicles to be seen.

Then passing to the taxicab plant the visitors followed through, from the millroom, to the body assembly, to the sheet steel department, to the sand-blasting section, and finally to the point where the lacquer finishing was in progress under ventilating hoods. Special interest was shown in the particularly staunch body-construction. When one considers that the average life of a taxicab is at least 200,000 miles, he realizes why the design and construction must be as it is. The capacity of the taxicab plant was said to be 50 per day.

The chassis-assembly department was the last of the features inspected, before the visitors thanked E. G. Knox, W. E. Moody and H. M. Stillman for having conducted them so courteously through the plant.

Paul H. Geyser, vice-president of the Company, was the host of the visitors, and he certainly "gilded the lily" by supplying de luxe transportation to and from the plant, and by providing a very delectable luncheon before the inspection started. Models of motorcoaches were distributed as souvenirs of the visit.

4 MILES OF EXHIBITS

Municipal Pier Radiant and Vibrant with Furnaces and Machines in Operation

Whoever among automotive engineers could not or did not spend a few hours at the Eighth Annual National Steel and Machine Tool Exposition in Chicago during the week of the Production Meeting and the convention of the American Society for Steel Treating, Sept. 20 to 25, has innumerable reasons for regret; and the purpose of this is to make him aware of it.

Never before have the steel and machine-tool industries staged such a complete, instructive and attention-compelling concentrated display of all that is best and newest in materials, equipment and methods in the metal-working line. Chicago's great Municipal Pier was filled from end to end of its mile length with the exhibits of 350 companies occupying spaces on both sides of two main aisles. With 80,000 sq. ft. of floor space filled, the exhibition was nearly 80 per cent larger than last year. It excelled not alone in size, but in action and attendance as well.

The whole interior of the closed-in pier was vibrant with the dynamic energy of heat-treating furnaces and machine-tools of all sorts in operation. Appeal to the eye was made by illuminated photographic transparencies and continuous motion-pictures of rolling-mill operations, while the sense of touch was intrigued by invitations to test the heat-insulating quality of some materials, warnings to keep hands off of adjacent hot firebricks and requests to guess the weight of castings. So altogether enticing was the extraordinary display, which raises this comparatively new claimant for public attention to first rank in size in the Country's annual industrial exhibits, that the daily attendance ran well into five figures.

Gas and Electric Furnaces in Operation

Especially noticeable were the many furnaces shown in operation, for heat-treating, carburizing, melting, and high-speed salt bath. Keen competition between the electric and gas types was evident. Continuous automatic gas-fired annealing ovens and electrically heated and automatically controlled furnaces for the continuous heat-treating of small parts, electric furnaces for smelting, and oil-fired furnaces all were exhibited in operation. In connection with these were shown automatic temperature-regulators, indicating and recording pyrometers, quenching tanks, and other accessories.

Samples of a great variety of steels were displayed, including new tool steels of claimed superiority for tools and dies, a steel having special new properties of toughness combined with easy working and good hardening characteristics, and various alloy-steels. The materials exhibits also included grinding materials, firebrick and others.

Among the great number of machines in operation were electric spot-welding machines; high-speed hack-saws cutting tool steel; a circular saw with inserted teeth cutting 100-lb. railroad rails; band saws cutting steel; high-speed sheet-metal cutting machines; high-speed drills; milling, boring, tapping, and forging machines; and shaping, lapping and grinding machines; as well as many others. In addition, of course, even a larger number of static machines were displayed.

Naturally, testing machines and instruments of all sorts were included among the exhibits, some operated manually and others by power. Among them were hardness and fatigue testing machines, pyrometers and so on.

In short, almost everything in the line of special steels and equipment for working them that is used in the automotive and other industries engaged in treating and working raw and semi-finished iron and steel into finished products could be seen. If one did not weaken in making the 2-mile trip to the end of the pier away out in Lake Michigan and back, he was sure to end the journey a wiser if a wearier man.

Four Who Played Various Parts in the Production Meeting

W. H. Eisenman (at the Extreme Left) Had General Charge, as Secretary of the American Society for Steel Treating, of the Exhibition on the Municipal Pier; John Yonger (Left Center) Presided at the Inspection Session; R. R. Keith (Right Center) Was Responsible for the Invitation To Visit the Tractor Plant of the International Harvester Co.; and R. M. Hidey (Extreme Right) Served on the Production Meeting Committee

NATIONAL MEETINGS CALENDAR

TRANSPORTATION AND SERVICE MEETING—Copley-Plaza Hotel, Boston—Nov. 16 to 18

TRACTOR MEETING—Hotel Sherman, Chicago—Dec. 1 to 3

ANNUAL DINNER—Hotel Astor, New York City—Jan. 13, 1927

ANNUAL MEETING—Detroit—Jan. 25 to 28, 1927

SEMI-ANNUAL MEETING—French Lick Springs, Ind.—May 25 to 28, 1927

HEARTY THANKS TENDERED

Members of the Various Production Meeting Committees Deserve Commendation

The committees that were responsible for the success of the Production Meeting include the persons listed below. Those men who participated in various capacities in planning the meeting and carrying it through to a satisfactory issue can rest assured that their efforts are and will be fruitful of progress in the Society's program for production men.

PRODUCTION MEETING COMMITTEE

V. P. Rumely, *Chairman*

George Babcock	R. R. Keith
Eugene Bouton	Joseph Lannen
W. G. Careins	L. F. Maurer
C. B. Durham	T. Milton
A. H. Frauenthal	P. J. Moohan
Paul Geyser	Louis Ruthenburg
R. M. Hidey	P. L. Tenney

LOCAL COMMITTEES

FACTORY INSPECTION COMMITTEE

O. W. Young, *Chairman*

P. J Moohan Robert Stortz J. W. Tierney	Visit to Nash Motors Co.
Paul H. Geyser F. D. Gaskill Lee Oldfield	Visit to Yellow Truck & Coach Mfg. Co.
R. R. Keith D. P. Baker J. S. Erskine	Visit to International Harvester Co.

RECEPTION COMMITTEE

Taliaferro Milton, *Chairman*

C. J. Blakeslee	C. A. Peirce
W. J. Buettner	F. G. Whittington
Lee Oldfield	R. E. Wilson

SPEAKERS AND CHAIRMEN

Special mention should be made of the very interesting and valuable papers that were prepared by the production men listed below:

John Bethune	N. H. Preble
Charles L. Cameron	P. W. Rhame
A. R. Fors	Clarence A. Brock
A. H. Frauenthal	J. B. Scott
Walter G. Hildorf	C. S. Stark
O. C. Kavle	E. R. Stoddard
Paul Phelps	R. R. Todd

The technical sessions were very skillfully managed by the following chairmen: Eugene Bouton, W. G. Careins, Robert S. Drummond, and John Younger.

HOSPITALITY APPRECIATED

Through the generosity of Paul Geyser of the Yellow Truck & Coach Mfg. Co., one of the most interesting inspection visits was provided. The company just mentioned also furnished transportation to and from the factory and served an excellent luncheon to the visitors.

Through the courtesy of P. J. Moohan, the plant of the Nash Motors Co. at Kenosha, Wis., was thrown open to inspection.

R. R. Keith was responsible for the invitation that provided for the inspection of the tractor plant of the International Harvester Co.

The helpfulness of the companies and executives abovementioned was but another example of the interest in Society work and the desire to assist in its promotion that has always been in evidence. It is very gratifying to Society members to be assured of this spirit of cooperation.

PRODUCTION ADVISORY COMMITTEE

Standards Committee Division Members Also Consider Future Work

Eugene Bouton, of the Chandler Motor Car Co., was unanimously elected chairman of the recently-formed Production Advisory Committee, when the members of that committee met in joint conference with the Production Division of the Standards Committee in Chicago on Sept. 22. Other members of the Advisory Committee are W. G. Careins, Paul H. Geyser, V. P. Rumely, E. N. Sawyer, and E. A. Taylor.

General Manager Clarkson, chairman pro-tem of the conference, vacated the chair in favor of the newly-chosen chairman of the Advisory Committee. From R. S. Burnett, Standards Manager, Chairman Bouton requested an outline of the proposed activities of the Advisory Committee. Briefly, the object of the unit was said to be the initiation and coordination of the various production activities in which the Society is so vitally interested. Chiefly in an advisory capacity the committee would participate in planning and correlating standardization and research work, meetings and sections production work, schedules of production papers for publication, and other active interests. Chairman Bouton reported that his committee would formulate a definite program of work in the near future.

W. G. Careins, chairman of the Production Division of the Standards Committee, stated that the members have been conducting a survey to determine the most suitable procedure in the standardization of grinding wheels, this being the first project undertaken by the Division. It was stated that the use of the standards already promulgated by the grind-

ing wheel manufacturers would be furthered insofar as they apply to automotive work.

The other principal work of the Division at this time is the reviewing of reports issued by sub-committees of the Sectional Committee on Small Tools and Machine-Tool Elements that was organized under the sponsorship of the Society, the National Machine Tool Builders Association and the American Society of Mechanical Engineers. Reports on T-slots and parts and tool holders and toolpost hole openings have all been sent to the Division for its consideration. Other subjects on the present schedule of the Sectional Committee are machine tapers and milling cutters on which investigations of present practice are now being conducted.

John Younger, of *Automotive Abstracts*, proposed that the Advisory Committee give consideration to the preparation of job specifications establishing the requirements as to qualifications and experience of operators for any given job.

The following persons attended the meeting: G. E. Bechtel, White Motor Co.; Eugene Bouton, Chandler Motor Car Co.; R. S. Burnett, Society of Automotive Engineers, Inc.; W. G. Careins, Ajax Motors Co.; C. F. Clarkson, Society of Automotive Engineers, Inc.; E. F. DuBrul, National Machine Tool Builders Association; A. H. Frauenthal, Chandler Motor Car Co.; P. H. Geyser, Yellow Truck & Coach Mfg. Co.; William J. Harris, Studebaker Corporation of America; O. C. Kavle, Manufacturers Consulting Engineers; Fred E. A. Kline, Pierce-Arrow Motor Car Co.; L. F. Maurer, Studebaker Corporation of America; E. N. Sawyer, Cleveland Tractor Co.; F. W. Stein, Fairbanks Morse & Co.; E. A. Taylor, Yellow Sleeve Valve Engine Co.; John Warner, Society of Automotive Engineers, Inc., and John Younger, *Automotive Abstracts*.

TRANSPORTATION AND SERVICE MEETING

November Event in Boston Appeals Strongly to Motorcoach and Truck Operators

For the consumption of persons interested in automotive transportation, especially the operators of motorcoaches and trucks, no more attractive program of papers and speakers could be imagined than that scheduled by J. F. Winchester and the members of his committee who will be responsible for the Transportation and Service Meeting that will be held at the Copley-Plaza Hotel in Boston, Nov. 16 to 18. Following is a schedule of addresses with the names of speakers who have accepted the committee's invitation to take part in the meeting.

Motorcoach—Truck—Railroad Session

Motorcoaches and Trucks in Railway Service—B. V. Crandall, president, *Railway Review*.

Motorcoach and Railroad Operation Coordinated—A. P. Russell, New England Transportation Co.

Economics of Motor-Vehicle Transportation Correlated with Steam and Electric Railroads—G. L. Wilson, Wharton School of Finance and Commerce, University of Pennsylvania.

Maintenance Session

Fleet Maintenance—F. P. Freeman, Public Service Transportation Co.

Maintenance with Especial Reference to Tool Equipment—A. H. Leipert, International Motor Co.

Freight Handling Session

The Coordination of Railroad and Trucking Operations—F. I. Hardy, Boston & Maine Railroad.

The Coordination of the Container with Rail and Road Transport Facilities—W. P. Kellett, Brantford, Ont., Canada.

Motorcoach and Truck Operation Session

Truck Operation—C. S. Lyon, Motor Haulage Co.

Modern Motorcoach Operation—G. T. Seely, Chicago Motor Coach Co.

Brake Requirements for Trucks and Motorcoaches—M. B. Morgan, Timken Detroit Axle Co.

Tire Session

Effect of Tire Equipment of Trucks and Motorcoaches on the Road—Representative of the Bureau of Public Roads.

The Operator's Tire Problem:

Cushions—Representative, Overman Cushion Tire Co.

Pneumatics—J. M. Linforth, Goodyear Tire & Rubber Co.

Solids—Speaker not yet selected.

Transportation and Service Banquet

Prof. W. J. Cunningham, of Harvard University, an eminent authority on transportation problems, will deliver the principal address at the Transportation and Service Banquet that will be held at the Copley-Plaza Hotel on the evening of Nov. 17.

Hon. Alvan T. Fuller, governor of the Commonwealth of Massachusetts, has accepted the Society's invitation to address the banquet, on condition that he is in this Country at the time. It is expected that Hon. Frank Allen, lieutenant-governor of the Commonwealth of Massachusetts, will also honor the Society with a short address.

An Inspection Visit

The Standard Oil Co. has very courteously consented to open its Cambridge maintenance plant, one of the largest and best in the country, to the inspection of those who attend the meeting.

A cordial invitation has also been received from the Massachusetts Institute of Technology for members and guests to visit the Institute and inspect the departments that are of especial interest to the automotive fraternity.

Watch for Details!

Between now and the date of the Boston meeting, there may be slight changes and additions in the schedule outlined above. These will be called to the attention of our members through the medium of the November issue of The Journal and *Meetings Bulletin* that will be circulated in due course.

Committee Personnel

J. F. Winchester, *Chairman*

H. R. Cobleigh	V. A. Nielsen
C. O. Guernsey	L. H. Palmer
A. W. Herrington	R. E. Plimpton
F. C. Horner	A. J. Scaife
F. E. H. Johnson	F. J. Scarr
A. F. Masury	E. W. Templin

G. S. Whitham

LOOKING 2 MONTHS AHEAD

December Tractor Meeting in Chicago with Agricultural Engineers

Arrangements have been completed for the presentation of the papers listed below at the two sessions of the Tractor Meeting that will be under the auspices of our Society. Other interesting addresses have been arranged by the American Society of Agricultural Engineers for the sessions that will be under the management of that Society. The Tractor Meeting as indicated above, will be a cooperative affair with Dec. 1 and 2 devoted primarily to agricultural topics and Dec. 3, S.A.E. day, set aside for matters dealing with the automotive aspects of tractor engineering.

Papers and Speakers

Production of Tractors and Farm Equipment—Speaker not yet selected

Utilization of Heavy Fuels in Tractor Engines—R. M. Anderson, Holley Carburetor Co.

Industrial Application of Tractors (with movies)—Mr. Parrish, International Harvester Co.

Application of Tractors and Automotive Equipment to Road Building and Maintenance—Representative of the Bureau of Public Roads

Additional details concerning the Tractor Meeting will appear in the November issue of THE JOURNAL and in editions of the *Meetings Bulletin* that will be circulated well in advance of the meeting date.

COMMITTEE PERSONNEL

O. W. Sjogren, *Chairman*
J. F. M. Patitz O. W. Young
O. B. Zimmerman

NEXT SUMMER MEETING AT FRENCH LICK

Meetings Committee Projects Plans and Makes Recommendations to the Council

At a recent conference in Detroit, the Meetings Committee discussed a number of important matters and formulated plans for future activity. Members will be interested to know that the committee has recommended to the Council that the 1927 Semi-Annual Meeting be held at French Lick Springs, Ind., the site of the very successful Summer Meeting this year. May 25 to 28, the days preceding the Indianapolis races, were selected as the most suitable for this important combination of business and pleasure pursuits.

The committee decided to hold the Annual Dinner at Hotel Astor, New York City, on Jan. 13, 1927, the Thursday of show-week.

The Annual Meeting was scheduled for Detroit, Jan. 25 to 28, 1927, the days preceding the Chicago automobile show. Topics and speakers were chosen for eight or ten technical sessions and the committee recommended that a carnival be held on the evening of Jan. 28 as the closing event of the Annual Meeting.

PAPERS REQUESTED

The Meetings Committee takes this occasion to urge that members who desire to present or to have presented technical papers on pertinent automotive engineering topics communicate at once with headquarters. It should be realized that the program for an important national meeting is invariably arranged months in advance of the meeting date. Suggestions should therefore be transmitted promptly.

THOSE PRESENT

Those who attended the Meetings Committee conference in Detroit on Sept. 9 are included in the following list:

L. Clayton Hill, *Chairman*

D. E. Anderson	V. P. Rumely
J. H. Hunt	W. R. Strickland
A. L. Knapp	John Warner
B. J. Lemon	F. E. Watts
T. J. Litle, Jr.	Paul Weeks
George McCain	F. A. Whitten

METROPOLITAN CONVINCES THE LADIES

200 Section Members and Guests Frolic at Manhassett Bay Yacht Club

"Let's have another frolic soon!" was the general demand heard by Chairman F. K. Glynn and other Metropolitan Section officers and committeemen who were responsible for the success of the Metropolitan Section Frolic that took place at the Manhassett Bay Yacht Club on Sept. 15. The truth about the matter is that everybody had a wonderful time, first on the motorcoach ride through the beautiful scenery of Long Island, then at the dinner and dance and finally on the return trip in the luxurious motorcoaches that were furnished through the courtesy of L. E. Voght, American Car & Foundry Motors Co.; A. F. Masury, International Motor Co.; H. A. Hegeman, National Railway Appliance Co.; A. W. Spence, Pierce-Arrow Motor Car Co.; and W. J. Sommers, White Motor Co.

THEY'RE OFF!

Leaving Society Headquarters at 6:15 p. m., the merry party proceeded on the 20-mile excursion and arrived in the midst of the Yacht Club's pleasant surroundings with a healthy appetite that made the call for dinner a most welcome sound. Immediately, paper hats appeared, countless toy balloons journeyed from table to table and the air was filled with weird noises from tin whistles, music boxes and rattles for the younger members.

Soon the pandemonium was replaced by the well-known harmony produced by Joseph Knecht and the Silvertown Cord Orchestra that has been heard by millions of radio enthusiasts throughout the United States. Right at this point Mary and George, Bill and Phyllis, Charlie and Gladys,

SCHEDULE OF SECTIONS MEETINGS

OCTOBER

1—WASHINGTON SECTION—What Makes a Spark-Plug Spark?—Dr. F. B. Silsbee

4—CLEVELAND SECTION—What Is the Field of Bus and Coach on Electric Railways, for Co-Ordination, Alternation or Rail Replacement?—Walter Jackson
The Public Reception of Motorcoach Service in Cleveland—C. M. Ballou

5—BUFFALO SECTION—Quantitative Effect of Engine Carbon on Detonation—Neil MacCoull

7—DETROIT SECTION—Sound and Its Measurement—Floyd A. Firestone

8—SOUTHERN CALIFORNIA SECTION—Testing of Gasoline and of Oil, of Engines and of Steel—R. W. Stewart and T. A. Fitch

12—CHICAGO SECTION—Outing: Golf in the Morning; Noon Luncheon at Country Club; Visit to Gary Plant of Illinois Steel Co. in the Afternoon

14—INDIANA SECTION—Shimmy and Tramp—Representative from Eaton Axle & Spring Co.; discussion to be led by L. R. Buckendale
NEW ENGLAND SECTION—Brakes

21—METROPOLITAN SECTION—Aviation—Lieut. G. O. Noville and A. G. H. Fokker

in fact most of the boys and girls, spurned the food temporarily in favor of a fox trot. From then on it was a case of dine and dance, and dance and dine, until the last motorcoach started its homeward journey at midnight. With a Paul Jones and several lucky-number dances the members and guests became thoroughly acquainted, and the opening event of the Metropolitan Section's year of activity had achieved its purpose.

Now, when George tells Mary that he is "staying in town" of an evening for a Metropolitan Section Meeting, Mary will at least know that there *is* a Metropolitan Section and that to attend one of its meetings is in all probability an opportunity that George should not ignore. In short, the ladies were convinced.

Committee Tenders Thanks

F. K. Glynn, chairman of the Metropolitan Section, has asked that THE JOURNAL express the hearty thanks of the committees and members that participated in the frolic to those persons and companies above mentioned that furnished the excellent motorcoach facilities.

The committee also greatly appreciated the cooperation of S. R. Milburn in providing the Silvertown Cord Orchestra on behalf of the B. F. Goodrich Rubber Co. Prizes and favors were very generously provided through William A. Shoemaker, Goodyear Tire & Rubber Co.; A. C. Bergmann, C. G. Spring & Bumper Co.; R. C. Porter, Stromberg Motor Devices Co.; William E. Kemp, Byrne, Kingston & Co.; and Phillip Morris & Co.

PROPHECIES OF FUTURE DEVELOPMENT

Horning Talks Forcefully to Indiana Section on Trends of Automotive Design

Announcement of the tentative plans of the Indiana Section for the activities of the coming year; the inauguration of the new Chairman, Ralph Teetor, chief engineer of the Indiana Piston Ring Co.; and an address on the Trends of Automobile and Engine Design by H. L. Horning, president and general manager of the Waukesha Motor Co., Waukesha, Wis., were the main features of the opening meeting of the season which was held on Sept. 9, in the roof garden of the Hotel Severin, Indianapolis. An interesting introductory feature was the exhibition of lantern slides showing many of the early automobiles that were in vogue from 1900 to 1902, which, by contrast with the types now prevailing, served to visualize the amazing forward progress the automotive industry has made since that period.

Mentioning that engineering achievement is from 1 to 5 years ahead of the economic possibilities in sales, due to the length of time needed to make changes in equipment, to educate the public and the service men and thus to put a new idea into effect, Mr. Horning remarked also that the fundamentals of engineering are being more intensively considered than ever before. In his racy outline of present practices and future probabilities, in reference to design, he enumerated present hindrances to progress and proffered incisive and constructive criticism thereof.

Among the many subjects touched upon by Mr. Horning, he referred to the respective merits of four, six and eight-cylinder engines, believing the six-cylinder engine best for passenger-car purposes and thinking the eight-cylinder engine legitimate for racing cars and aircraft. He felt that no need exists for the transmittal of engine vibration to the chassis and intimated that insulation from such vibration can be accomplished by some form of spring-suspension. In connection with the weights of pistons and the use of aluminum, he said that aluminum requires much better lubrication than does iron. In general, he thought that great progress has been made within the last few years toward solving lubrication difficulties. Clean oil and sufficient oil are requisites. Starting, particularly in cold weather, and idling or working under light load are the main reasons for the destruction of cylinders and bearings, and the speaker said also that the engine that works hard is the engine that has long life. For the main bearings and the connecting-rods, forced-feed lubrication is a necessity; for cylinder-wall lubrication, some means should be provided so that the walls get a bath of fresh oil at all times, especially when starting.

Distribution of the fuel-mixture charge was discussed and the most important part of the explosion was said to be the instant after the explosion starts. With regard to acceleration, high compression is an important factor, but improvements in fuel and in design are needed to enable the effective use of it. Gear-ratios have an important influence on acceleration, on the life of the vehicle and on its maintenance, and the subject of proper gear-ratios is worthy of research study. The attempts to increase the compression, provide clean oil and secure better distribution have been and are features of the development of engines for motorcoach service. Mr. Horning sees a possibility of the use of superchargers on motorcoach engines. For the smaller sizes of truck, he thinks the engines will have cylinders of small bore and that great attention will be paid to proper balance and smooth running.

In the discussion which followed, Charles S. Crawford, F. S. Duesenberg and H. A. Huebotter were the principal speakers and they debated with Mr. Horning various phases of the points made in his address.

The Two Attractions at the September Meeting of the Indiana Section

H. L. Horning (at the Left) Spoke on the Trends of Automobile and Engine Design and R. R. Teetor (at the Right) Was Installed as Chairman for the Ensuing Year

SEASON OPENS FOR CLEVELAND SECTION

Inspection Trip, Sports Program and Dinner Constitute 1926-1927 Inaugural

Members and guests of the Cleveland Section, in number about 100, made a pilgrimage to Canton, Ohio, on Sept. 16, as a kind of inaugural ceremonial with which to begin the Section's activities for the coming season. On arrival, they became guests of the Timken Roller Bearing Co., were formed into groups and ushered through the bearing plant and the steel mill on an inspection trip that proved most interesting. Following this instructive experience, the party adjourned to the Congress Lake Country Club where all were served with luncheon.

A sports program, including track and other athletic events, driving and putting contests for golf honors, was in progress during the afternoon, and great admiration was expressed for the elegant prizes that were awarded. A dinner at the Club in the evening, tendered by the Timken Company, rounded out the eventful day. All agreed that the company excels as a host. It was a tired but satisfied, appreciative and happy bunch that wended its way homeward to Cleveland. No doubt exists that the Section will, after such an energetic and stimulating start, set a record-breaking pace in Section work.

AIR TRANSPORT IN EUROPE

EUROPE is today criss-crossed with air-lines. Airplanes are operated daily or more frequently on regular schedule, between nearly all the capitals and principal business centers of the Continent. The business man, the statesman or the tourist can travel all over Europe by air effecting great savings in time and at approximately the same rates as first-class railroad charges.

Great rivalry exists between the different countries in the exploitation of international lines while all internal traffic is usually restricted to nationals. The larger nations are pushing their international lines farther and farther afield to establish quick communication with regions where they wish to enlarge their political and commercial influence and advertise national aircraft products.

Situation in Germany and France

Germany affords the key to the present European situation. With the air forbidden to purely military craft, the Germans have turned their aeronautical energies to commercial aviation in the growing belief that through aviation they can regain much of their former political and commercial prestige. Although handicapped by allied restrictions, Germany has established itself in a dominant position in European aeronautical affairs and recently successfully negotiated the removal of the last of the allied limitations on purely commercial aircraft.

In addition to providing direct subsidies and navigational aids the German government has attempted to popularize aviation. Light airplane and glider contests have met with hearty support and have been responsible for definite advances in design. Aeronautical education is given in the schools and air-lines are widely advertised. When the attention paid to the comfort of the traveler in designing equipment and the low charges are considered it is not surprising that there should be more local passenger traffic in Germany than in any other European country. An encouraging feature of this traffic is the fact that it consists chiefly of German business and professional men and depends but little on transients.

French aircraft factories are working at top speed chiefly on government and export orders as domestic commercial demand is far from contributing effective support. Approximately 250 airplanes are in use in air transport, which at a depreciation rate of 25 per cent would require annual replacement to the extent of 50 or 60 airplanes compared with an estimated production in 1925 of more than 3000. Government control of aeronautical activities is highly centralized and its support of air transport is exceedingly liberal.

French commercial aviation is in the hands of five companies which in 1926 were operating over 8000 miles of airway. A group of airways connects with the French colonies of north and west Africa by seaplane service across the Mediterranean and by landplane via the Spanish coast. This latter project is the most ambitious of all and has been the most successful, particularly in the carriage of mails. In 1924 this one company carried 99 per cent of all French and 89 per cent of all European air-mail traffic. Last year an extension to Dakar on the coast of West Africa was opened. French ambitions conceive of a line across this stretch of the Atlantic continuing down the coast of South America. The 1926 Aircraft Year Book reports that service is already available between Pernambuco and Buenos Aires.

British Policy and Air Services

Commercial aviation in Great Britain was instituted with the avowed purposes of building up a military reserve and putting the aircraft industry on a self-supporting basis. Originally only indirect assistance was granted but competition with French subsidized services soon forced the payment of subsidies to English companies. Even so they had a hard time and in 1924 a consolidation of four companies was effected.

British air services are chiefly international. Service between London and Paris in the summer is given three times daily each way and on one trip the line is extended to Basel and Zurich. The London-Amsterdam line last year was continued to Berlin and the London-Brussels line to Cologne after successful negotiations with Germany. In the passenger field British air-lines have been losing ground in the last 2 years to Continental lines. In 1922 and 1923 British airplanes carried 77 and 79 per cent respectively of all passenger traffic between England and the Continent; last year this percentage dropped to 51 as a result of an improved safety record and more satisfactory service by Continental lines.

Great Britain's aeronautical ambitions lie in the direction of a great network of airways bringing into closer contact the widely separated portions of the empire. To India in 4 days and to Australia in 6 days instead of 6 weeks is the present aim. Military personnel and equipment are being used on a mail line between Cairo and Karachi, India, while commercial operations on this line are contemplated for next year. Two large dirigibles are under construction for experimental work between England, India and Australia and airship bases on this route are now being prepared. Eventually it is hoped to establish transatlantic service to Canada and the United States.

Activity in Other European Countries

In other European countries the same keenness for air transportation is displayed. A company in the Netherlands is operating a fleet of 14 modern airplanes to England, France and Germany. The misunderstanding between Germany and the western powers made Holland an important entrepot for air traffic between western and eastern Europe. In 1925 11 machines arrived daily at Schiphol, the airport of Amsterdam.

Russia, with German cooperation, is rapidly building up an extensive system of airways. Seven companies have been organized in Italy and service is available on three lines covering 3000 km. (1864 miles) while a number of other lines are contemplated. Belgium, Denmark, Sweden, Switzerland, Hungary, Finland, Czechoslovakia, and Poland among other countries have established lines of their own.

Earnings Are Small

None of these lines is as yet economically independent and some of them are reputed to earn a very small proportion of their expenses. One reason for this is the intense competition resulting from the fact that for military reasons all nations great and small have entered the field. Government regulation and red tape tend to increase the cost of production, and the desire to be able to transform commercial craft into military weapons results in the incorporation of inefficient features, such as excessive power. The subsidy, moreover, is credited with reducing to the minimum the incentive to make receipts meet expenses and in many cases certainly has resulted in charges that bear little relation to operating expense. In Germany, for instance, passenger fares are on the average lower than first-class railroad rates and decidedly out of proportion to costs.

Signs of improvement, however, are not lacking. A growing movement toward international cooperation culminated late last year in the formation of the International Air Traffic Association which promises much toward eliminating cut-throat competition. The growth of traffic is in many cases distinctly encouraging and a number of lines afford promise of achieving prosperity. The London-Paris cross-channel flight of 2 hr., for instance, gives real service in avoiding the necessity of transferring from train to boat and back again and in modifying the rigors of customs examination. Heavy tourist traffic is likewise a welcome source of revenue. The charges of £5 5s. average 12 cents per passenger-mile, which is not out of proportion to the

(*Concluded on p.* 342)

STANDARDIZATION ACTIVITIES

The work of the Divisions and Subdivisions of the S.A.E. Standards Committee and other standards activities are reviewed herein

A CRITIQUE OF THE S.A.E. HANDBOOK

In the September issue of *Mechanical Engineering*, J. B. Armitage[1] wrote a very interesting review of the first issue of the S.A.E. HANDBOOK published by the Society in bound form. This review is abstracted hereinafter as it is believed that the Society members will appreciate Mr. Armitage's comments and criticism.

Men give their time for the formulation of standards with the hope, and sometimes with the expectation, that the use of the standards evolved will ultimately become almost universal. The formulation involves considerable expense, and this expense is justified only when the resulting standard meets the general approval of the industry and is freely adopted. The use of a standard cannot be forced upon an industry, but if it has merit it will be quickly adopted if the necessary information is put in usable and easily understandable form and, most important of all, made readily available whenever needed.

The S.A.E. HANDBOOK is probably the most successful means used to date to get the standards adopted by an engineering society into the hands of the user, and it is undoubtedly responsible for a large part of the success of the S.A.E. standardization program. The new bound-volume edition should prove even more valuable to the membership, for the user can now be sure that his book is uptodate and that he is not using a standard that has been changed or has become obsolete, for S.A.E. Standards do change. A too common conception of standardization is the setting of rigid standards and specifications that prohibit all change or progress and limit individuality. S.A.E. Standards are continually reviewed in the light of progress, and from time to time such changes are made as become necessary or desirable to keep the standards uptodate. Heretofore these changes have been taken care of by issuing new loose-leaf sheets to the membership twice a year, but in the future it is intended to revise and furnish a new bound volume semi-annually. . . . . .

While many of the standards and specifications refer to articles of direct interest only to the automotive industry, the majority are being used with equal profit in the machine-tool and many other fields of general machine design. It is inconceivable that a book containing these standards and recommended practices that are reliably estimated to have produced a saving of at least 15 per cent of the total annual retail value of American automotive products, should not be read with interest and used with profit by all mechanical engineers interested in general machine design.

Probably the S.A.E. Standards best known and most used outside of the automotive industry are the specifications and heat-treatments for automotive structural steels, now generally known as S.A.E. Steels. This list contains specifications for 63 different steels, with recommended heat-treatments for most of them, and very conveniently arranged charts giving the physical properties of the more commonly used steels when heat-treated and quenched in either oil or water. The non-ferrous-metal specifications contain recommended mixtures for solders, babbitts, light alloys, and bronzes.

Other standards and recommended practices that can be followed to good advantage in general machine design are the 4, 6, 10, and 16-spline fittings; square, taper and serrated shaft-fittings; castle-nuts; lock-washers; flexible steel and non-metallic conduit; storage-batteries; insulated cable; cable terminals and clips; ball and roller-bearings; tube fittings; brake-lining; felt; silent and roller-chains and sprockets; flexible-coupling discs; friction-clutch facings; and many articles of minor importance or for occasional use.

The abstract of the report of the Sectional Committee on the Standardization and Unification of Screw-Threads, giving the necessary information for the use of the new American Standard Screw Threads, supplies this information in a very usable form. This standard has been approved as an S.A.E. Standard.

The section on automobile nomenclature is particularly good and is recommended to other engineering societies as an example of what can be done in a much neglected field.

Some advertising is included at the back of the book, limited, however, to S.A.E. Standard articles and materials. An index of makers of S.A.E. Standard parts and materials is included, but as it is limited to those advertising in the handbook, it is necessarily very meager. It would be very desirable and useful if extended. The chief criticism of the make-up of the book is that the index, being placed in front of the advertising pages, is not readily found.

Standardization of the manner of presentation of standards and of methods of getting the information to the men responsible for putting the standards into use is badly needed, and the S.A.E. HANDBOOK should prove to be a good precedent for other societies to follow.

The automotive industry is to be congratulated on having a society possessed with the foresight to make standardization one of its major activities—with members giving freely of their time for standardization work—and on having the S.A.E. HANDBOOK to get the standards directly into the hands of the users.

The September issue of the S.A.E. HANDBOOK was mailed to the members during the last 2 weeks of Septmeber. Members who have not received their copies should notify the Society in order that lost copies can be traced.

[1] Chief mechanical engineer, Kearney & Trecker Corporation, West Allis, Wis.

DEPTH OF TAPPED HOLES IN ALUMINUM

A member of the Society recently inquired for general information that would be of assistance in establishing the length of engagement of cap-screws or studs in holes tapped in aluminum. The inquiry was referred to E. H. Ehrman, of the Standard Screw Co., as Chairman of the S.A.E. Screw-Threads Division. Mr. Ehrman's comments are believed to be of sufficient interest to members to warrant reprinting them in THE JOURNAL.

If the depth of engagement were based on the strength of the screw and the resistance to shear of the threads in the tapped hole, the length of engagement would, without doubt, be far beyond present practice and perhaps impossible with hand taps in

which the shank is as large as or larger in diameter than the diameter of the thread as this would limit the depth of tapping to the length of the usable thread on the tap. It seems to me that a satisfactory scheme could be worked out, based on the length of the usable thread on the cap-screw. For coarse threads, this is $2D + \frac{1}{4}$ in., the $\frac{1}{4}$ in. being added as this is the average difference between successive lengths of cap-screws. If the mating parts can be machined accurately, practically the entire length of the usable thread can be used; otherwise it would be better to allow a margin of safety of not less than $\frac{1}{8}$ in., leaving the maximum depth of the usable thread in the tapped hole $2D + \frac{1}{8}$ in. The $\frac{1}{8}$ in. would be of more value for holes in the smaller diameters than in the larger sizes. A scheme such as the above would permit the use of standard cap-screws.

There is no uniformity among manufacturers with reference to the length of threads on studs, the average length of thread on the tap end averaging probably $1\frac{1}{2}D$. The great bulk of studs used, however, are made up to customers' specifications, so that the length of thread on the tap end could be made the same as it is for coarse-thread cap-screws. If it is desired to use standard studs, some degree of additional strength may be obtained by drilling a clear hole about $\frac{3}{4}D$ in depth, so that the shoulder of the stud is below the surface of the part into which it is screwed. While this practice does not increase the strength of the thread in shear, it is a safeguard against conical fracture, especially in the case of cast metal, and is of value to the extent that it increases the base of the fracture cone.

The use of thread engagements greater than $2D$ should not be encouraged, as the factor of lead error becomes one of importance with excessive lengths of thread engagement; perhaps not so much, however, in aluminum alloys as in the firmer-cast metals.

STANDARDS YEAR BOOK ISSUED

Publication of American Engineering Standards Committee Indicates Progress

The movement toward standardization of industrial products has been considerably extended during the last year and savings from standardization in American industry are constantly growing in magnitude, according to the Year Book of the American Engineering Standards Committee, just issued. More than 200 definite standardization projects are in process or completed under the rules of procedure of the Committee, and 365 national trade associations, technical societies and Government bureaus are cooperating in the work through some 1600 representatives.

For the convenience of American industry, the American Engineering Standards Committee is maintaining a file of specifications to be sold at cost. These include standards issued by all of the foreign standardizing bodies, with which the Committee regularly exchanges information and copies of standards, and also those of all the national trade associations and technical societies in the United States that have issued standards and specifications. This is done as a means of cooperation in the important work presented in the National Directory of Commodity Specifications, recently published by the Department of Commerce. The extensive file of specifications maintained by the Committee is referred to constantly by engineers and experts in every field. About 7000 standards are available for examination in this way.

The increase in the interest on the part of industrial executives in the standardization movement has been marked. Management has recognized more and more that standardization has an important part to play in the improvement of the processes of industry, in broadening its markets and in reducing costs of production.

The Society of Automotive Engineers is a member body of the American Engineering Standards Committee, having three representatives, C. M. Manly, B. B. Bachman and C. F. Clarkson, on the Main Committee. At the present time the Society has accepted sponsorship for the following Sectional Committees:

Aeronautic Safety-Code
Ball Bearings
Bolt, Nut and Rivet Proportions
Motor-Vehicle Lighting Specifications
Numbering of Steels
Pins and Washers
Screw-Threads
Small Tools and Machine-Tool Elements
Transmission Chains and Sprockets

The Society is also represented on the following Sectional Committees:

Brakes and Brake Testing
Code on Colors for Traffic Signals
Gears
Insulated Wire and Cable
Machine-Tool Safety-Code
Plain Limit-Gages
Scientific and Engineering Symbols and Abbreviations
Use, Care and Protection of Abrasive Wheels
Zinc-Coating of Iron and Steel

Copies of the Year Book may be obtained upon application to the office of the American Engineering Standards Committee, 29 West 39th Street, New York.

PATENTS ON ALUMINUM BRONZE

In the September issue of the S.A.E. HANDBOOK the patent note with reference to the liability of the Society regarding the infringement of patents that may apply to materials made to S.A.E. Specifications appears in connection with S.A.E. Specifications No. 68 and 69 for Cast Aluminum Bronze and Wrought Aluminum Bronze respectively.

This note has been included as the Patents Committee understands that possibly the compositions specified for these specifications cannot be used without infringement of existing patents. The patent note reads as follows:

> The adoption of S.A.E. Standards and Recommended Practices by the Society does not insure that users of constructions that incorporate such standards or recommended practices will not be liable for infringement of patents that may exist or may hereafter be issued, and does not constitute a recommendation of any patented or proprietary rights that may be involved.

MACHINE-TOOL STANDARDIZATION

Subcommittees on Small Tools and Machine-Tool Elements Hold Meetings

At the time of the New Haven Machine-Tool Exhibit in the Mason Laboratory of Yale University, Sept. 7 to 10, material progress was made by several of the Subcommittees of the Sectional Committee on Small Tools and Machine-Tool Elements. The Sectional Committee was organized under the sponsorship of the American Society of Mechanical Engineers, the National Machine Tool Builders' Association and this Society, under the procedure of the American Engineering Standards Committee, and is carrying its work forward through Subcommittees on T-Slots and Parts, Tool-Holders and Tool-Post Openings, Machine Tapers, and Milling-Cutters. The Subcommittee on T-Slots and Parts has issued a report that has been referred to the members of the Production Division of the Society's Standards Committee and a report is soon to be circulated by the Subcommittee on Tool-Holders and Tool-Post Openings. At the New Haven meetings, considerable progress was made in connection with formulating standards, particularly for the mounting dimensions of milling-cutters and a plan was consummated for gathering detail data from all the machine-tool builders on

the various tapers and dimensions used for tool and work-holding purposes in machine-tools. It is generally recognized that machine tapers are an important element in machine-tool design and the Subcommittee handling this subject will therefore be relatively large and representative. Its next meeting is tentatively planned for some time in December when it is hoped sufficient data will be available to make a thorough study of current practice and requirements and to formulate a tentative recommendation.

The work of this Sectional Committee is of particular interest to the Production Division of the Society's Standards Committee and production men in the automotive industries and the work of the Subcommittees of the Sectional Committee will be referred to the members of the Division as it progresses so that the interests of the automotive industry can be served to the greatest extent and the work of the Sectional Committee guided adequately to meet the interests of that industry.

At a meeting of the Subcommittee on Woodruff Keys that was organized under the Sectional Committee on Shafting, which was held in New Haven on Sept. 10 during the Machine-Tool Exhibit, the comments that had been received on the proposed standard for Woodruff Keys were reviewed and discussed. In general, the recommendations resulting from the May 12 meeting of the Subcommittee met with approval. The question, however, arose whether the standard should be restricted to the dimensions of the keys or include recommended limits for the key-seats in the shaft and the key-ways in the hub. It was decided to be guided by the recommendations of the industry, and to this end the recommendation of the Subcommittee will be issued in two forms—one specifying only the dimensions of the keys and the other including recommended limits for the key-seats and two classes of fit for the key-ways in the hub. The latter is considered desirable so as to provide a drive-fit for use in large production automotive apparatus in which requirements are severe and also a looser fit for sliding pulleys or gears and general mill-work in which the close fits are not required. The report of the Subcommittee will include only the standard half-round keys in thicknesses from 1/16 to ⅜ in. and key diameters up to approximately 1½ in. The Subcommittee has cooperated with the British Engineering Standards Association in which the proposal for standardization originated, and it is probable that the report when finally completed will be acceptable to both British and American manufacturers and possibly to Continental European manufacturers who use Woodruff keys in inch dimensions.

BAKING ENAMEL PANELS INSPECTED

Paints, Varnishes and Enamels Subdivision Finds Results Still Indefinite

On Sept. 16 the Paints, Varnishes and Enamels Subdivision of the Passenger-Car Body Division held its second meeting in Detroit to inspect the exposure-test panels of black baking enamels, the first inspection of which was reported on p. 126 of the August issue of THE JOURNAL. The general appearance and lustre of all the panels under exposure, before the accumulated soot and dirt on them was removed, was considered satisfactory, although the lustre on the panels of three sets of samples was poor after the panels had been polished. None of the panels indicated deterioration by rusting and the adhesion of the enamels to the panels was fairly good in practically all cases. All panels showed some degree of surface checking after cleaning but in many instances this disappeared with polishing.

Although it had been hoped that the panels had been under exposure sufficiently long to enable the members of the Subdivision to draw some conclusions as to the best baking periods for the several samples, it was evidently too early to do so as the results were fairly uniform. This led to the conclusion that no pronounced results of exposure tests can be expected for some time, and it was decided to postpone the next inspection meeting that had been scheduled for about the middle of November, until about the first of next April, at which time it is expected that more noticeable changes will have taken place in the samples under exposure.

AERONAUTIC STANDARDS CANCELLED

Work To Be Limited to Specifications That Promote Interchangeability

At the Aeronautic Division meeting held on Sept. 1 in Philadelphia, it was decided that the policy of the Aeronautic Division should be to limit aeronautic standardization to specifications that promote interchangeability. The number of materials used in aircraft construction is so large that to cover them completely at this time would require an amount of effort that would be out of proportion to the value of the specifications.

With reference to the material specifications adopted by the Society during 1917 and 1918 and still retained in the S.A.E. HANDBOOK, it was felt that in line with the policy decided upon these specifications should be cancelled. The specifications involved and the pages on which they appear in the S.A.E. HANDBOOK follow:

Specification	Page
Rubber Hose for Gasoline	C48
Steel Wire Cable	C65
Reels for Cable	C69
Round High-Strength Steel Wire	C70
Steel Cable Loops	C74
Cellulose Acetate Dope	D131
Cellulose Nitrate Dope	D134
Spar Varnish	D136

Inasmuch as the conferences held periodically by the Army and Navy Air Services are resulting in unifying the Army and Navy Specifications, it was recognized that the Division should undertake no standardization work that would conflict in any way with the work of these conferences. As the specifications adopted by the Army-Navy Conferences will not cover powerplants of less than 200 hp., it was understood that the Aeronautic Division would have to extend many of the AN Standards adopted to meet the requirements of commercial aircraft equipped with the smaller types of engine. That proper consideration might be given to determining the AN Standards that should be adopted by the Society as S.A.E. Recommended Practice and to the form in which they should be adopted, it was considered desirable to appoint a Subdivision to review all the AN Standards and to recommend to the Division such standards as should be adopted as S.A.E. Recommended Practice, as well as the form in which they should be adopted.

In the July issue of THE JOURNAL, p. 13, was printed a comprehensive outline of aeronautic standardization possibilities that had been submitted to the members of the Aeronautic Division by Chairman Warner. This outline was discussed in detail at the September meeting. It was the consensus of opinion that specifications should be drawn up by the Division for the mounting of radial, vertical and V engines of less than 200 hp.; propeller-hubs; fuel-system controls; tank outlets and end fittings; instrument mountings; tail-skid shoes; and engine-starter mountings. It was felt that the Subdivision appointed to review the AN Standards should include in its report standards for tire and rim dimensions, wheel-hub dimensions and types of mounting, stream-line steel-tube dimensions, and fuel and oil-pipe dimensions. The standardization of shock-absorber cord rings, radiator connections, safety-belt attachment, fuel-gage mounting, rubber pads for shock absorption, detachable powerplant mountings, and nose radiator mountings was not considered important enough to warrant immediate consideration by the Division and these subjects were consequently tabled.

AUTOMOTIVE RESEARCH

The Society's activities as well as research matters of general interest are presented in this section

COMPROMISES IN HEADLIGHTING

Suggestions Based on Preliminary Observation with Four-Lamp Test Equipment

The experiments referred to in this article were carried out with the head-lamp test equipment designed for the cooperative headlight research of the Illuminating Engineering Society and this Society. The test sets were described recently in these columns[1]. The views set forth are those of one experimenter.

The one object of headlighting is to illuminate the roadway and surrounding objects so as to make night-driving safe. The one important limitation in providing such lighting is that others, particularly approaching drivers, must not be subjected to dangerous or uncomfortable glare. Statistics show that lack of sufficient light is a much more common cause of accident than is glare.

Keeping in mind these two essentials of adequacy and freedom from glare and forgetting for the moment existing regulations, what constitutes an ideal headlighting system? The answer is obvious: A light that shows with sufficient clearness all that the driver needs to see when the road ahead is free from approaching vehicles, and that projects only a very little light to the spot occupied by the eyes of an approaching driver, when such driver is in view.

Obviously no system of lighting can accomplish both objects at the same time. Since roads are neither level nor straight, the eyes of the driver may at times occupy almost any position in the lighting pattern thrown by the approaching headlights; hence no adequate lighting is possible that will not at times "glare" opposing drivers. In addition, the approaching driver occupies precisely the position of some of the objects most necessary to be seen by the opposing driver, such as other vehicles traveling in the same direction. Any practical lighting system, therefore, must be a compromise.

Two types of compromise have been applied. They may be termed compromise in space and compromise in time. Unfortunately, some tendency has been manifested to compromise in both respects. This should not be done.

Types of Headlight Compromise Compared

By compromise in space is meant the customary fixed-beam system. With a single fixed lighting-pattern thrown by lamps rigidly mounted on the car, the axis of the light-beam may be adjusted to any desired angle with the horizontal. Once adjusted, it necessarily follows all changes in direction, both horizontal and vertical, of the axis of the car body. As regards angle of tilt, therefore, the requisite compromise lies between an axis high enough for illumination of the road and low enough to avoid the eyes of the approaching driver. Were all roads flat and car loadings always uniform within an angle of 1 deg., such a compromise would do very well, but neither of these conditions holds. Were all highways straight, more light might be thrown above the surface on signs and objects at the roadside; but roads are not straight and such illumination would often glare the approaching driver.

With roads neither uniformly straight nor uniformly flat, the best possible compromise in space gives at times, as on approaching the foot of a hill, only 100 or 200 ft. of visible distance on the road surface; and, at other times, as on topping a hill, maximum light in the eyes of an approaching driver. No adequate lighting of road-signs or pedestrians and other objects at the roadside seems to be possible with the space-compromise type of light.

The compromise in time is brought about by the various devices for tilting or dimming lights, so that different light-patterns are used for clear-road driving and for meeting other cars. The compromise in this case involves the time when, on the approach of another vehicle, the light-pattern must be changed. It should not affect either of the two light-patterns. In other words, the driving-light may give the best pattern for open-road driving and the meeting-light may give the best possible illumination compatible with the interests of both drivers on meeting.

Self-Protective Feature of Adjustable Beam

The question now arises whether the driver having such adjustable equipment will or can be compelled to use it in such a way as to protect others on the road. Discussers of this phase of the subject have been somewhat pessimistic as to the courtesy of the average driver. Aside from legal enforcement, which seems possible where the violation is so obvious an act as failure to depress lights on meeting another car, certain practical considerations suggest that the proper use of adjustable lights may be easily secured.

For open-road driving at normal touring speeds, the driver must see all objects at the roadside, including instruction and warning signs, as well as dimly lighted vehicles such as trucks and wagons ahead. On all roads where touring speeds are safe very little light is needed on the road surface within 50 to 100 ft.; and, in fact, very little is desirable. A driving-light, therefore, should illuminate this part of the road only to a limited extent. On the other hand, a light to be satisfactory for meeting other vehicles should give a brilliant illumination for the 50 to 100 ft. of road immediately ahead, including the shoulder of the road and roadside objects; aside from the requirement of protecting the approaching driver. The latter consideration makes it imperative that practically no light shall be projected above the horizontal at any time, even when, on rough roads, the light is thrown up and down.

With a driving-light such as that described briefly above, the driver on meeting another car immediately needs more light in the foreground because the approaching lights make the low illumination in this part of the field entirely inadequate. He is forced in self-protection to depress his own lights, thus automatically protecting the other driver from glare.

This self-protective feature of a depressible beam combination was discovered by experiment, not deduced from reasoning. A considerable amount of driving with various types of illumination secured with the four-lamp experimental set led to its recognition. Its value and effectiveness, however, can hardly be appreciated without actual trial under various road conditions.

To summarize, the two types of compromise, in space and in time, may be compared as follows. The fixed-beam adjustment will give a moderately satisfactory but inadequate driving-light, with a certainty that the full intensity will at times reach the eyes of the approaching driver without any fault on the part of either driver. The adjustable-beam equipment will give an entirely safe and satisfactory driving-

[1] See The Journal, August, 1926, p. 122.

light and an adequate meeting-light with a chance that, due to failure to make the adjustment the full-beam intensity will reach the eyes of the approaching driver.

Which system would subject the driver more frequently to dangerous glare seems to be an open question. With the self-protective feature, however, and with legal enforcement if necessary, the adjustable system seems to have the advantage in respect to frequency of glare. It certainly has an immense advantage in safe illumination.

Device Suggested To Secure Beam Adjustment

The safety feature might be enhanced by arranging the system so that switching from one adjustment to the other would be accomplished by pressure of the left foot of the operator, the depressed beam being always in use except when the driver holds the button down. In this case, the minimum of effort is required for changing and the depressed lights are necessarily "on" automatically in case of any emergency.

SEPTEMBER COUNCIL MEETINGS

The first meeting of the Council this season was held in Detroit on Sept. 24. Those present were President Litle; First Vice-President Hunt; Councilor Chandler; Ernest Wooler; L. C. Hill, chairman of the Meetings Committee; C. B. Veal, C. B. Whittelsey, Jr., and C. F. Clarkson. One hundred and eighty-two applications for individual membership which had been acted on by letter ballot of the Council were reported and in addition 49 applications were submitted. The resignations of 8 members were accepted. Four reinstatements to membership were made; also 17 transfers in grade of membership. The members in arrears of dues for the fiscal year that closed on Sept. 30 were given until Oct. 15 to pay, in default of good reason to the contrary, on penalty of being dropped from the roll of membership.

In the period from Jan. 1 to Sept. 18, 1926, 621 applications for membership had been received, as compared with 522 aplications received during the same period of 1924, and 671 in 1925. On Sept. 18 there were 5960 on the rolls of the Society, including Affiliate member representatives, as compared with 5584 on the same day of 1925. From Jan. 1 to Sept. 18, 591 aplicants who had been elected qualified as members.

The financial report for 11 months of the last fiscal year was submitted, as of Aug. 31, 1926. The total income for the period was $324,219.88, this being $17,212.40 in excess of the expense. This is comparable with a deficit of $5,704.60 for the corresponding period of the fiscal year ended Sept. 30, 1925. A net balance of assets over liabilities of $169,830.16 was shown as of Aug. 31, 1926, this being $13,580.48 more than the corresponding figure on the same day of 1925. The total income for August was $27,013.50. The expense for the month was $23,260.92. In connection with the items of budgeted expense during the current fiscal year, it was estimated that the income of the Society for the year would be about $378,000.00.

The following were appointed on the Production Division of the Standards Committee: A. R. Fors, A. F. Misch, E. N. Sawyer and E. K. Wennerlund.

For service on the Sectional Committee on Standards for Drawings and Drafting Room Practice, the following were named: C. F. Drumm and M. C. Frins. The following were appointed to the Sectional Committee on Small Tools and Machine-Tool Elements: W. G. Careins, A. H. Frauenthal and E. N. Sawyer.

It was decided to accept, jointly with the American Society of Mechanical Engineers, sponsorship for the Sectional Committee for Standardization of Wire and Sheet-Metal Gages, under the procedure of the American Engineering Standards Committee.

C. B. Veal was appointed as a Society representative on the Engineering Division of the National Research Council.

President Litle was requested to represent the Society on the Contest Board of the American Automobile Association.

The next meeting of the Council will be held in New York City on Nov. 9.

AIR TRANSPORT IN EUROPE

(*Concluded from p.* 337)

expenses of efficient operation, and traffic in summer already approaches the necessary volume. The problem of increasing the winter traffic to a corresponding level, a problem common to all European lines, remains, awaiting for its solution the gradual elimination of the uncertainty attendant upon winter flying.

Experimental Work Under Way

Experiments with radio direction-finding apparatus and the development of Neon lights that emit a reddish glow, which is said to be visible through fog, are steps in the right direction. Multiple-engine airplanes are used exclusively on the Dutch lines and to a great extent on the French and British airways. With better inspection this practice accounts for the much greater freedom from forced landings than is the case with the United States Air Mail. The development of certain devices under experiment at present for better control of airplanes at low speeds promises better records of safety and reliability. Insurance coverage for all risks between London and the Continent already costs less for transport by air than by rail and boat.

Night-flying in Europe is still in the experimental stage. A lighted airway has been established between Paris and London and night flights have been made on certain line sections in northeastern Europe, but progress has been slow.

The soundness of European practice in subsidizing airlines has been frequently questioned. This is to be said for it: Europe has been given the benefit of service by air, companies are in operation accumulating experience and European countries are gaining control of the airways that lead to the great markets of the world. Airways, like landways, require concessions from the countries over whose territory they pass; aircraft operators, like competent sailors, are the product of years of training. Other things being equal, the first and longest in the field will be served best, and the manufacturing countries of western Europe may find themselves much more easy of access to world markets than the United States.—T. C. M. in *Commerce Monthly*.

Vol. XIX October, 1926 No. 4

Conveyors Used in the Automotive Industry

By C. A. Brock[1]

Production Meeting Paper *Illustrated with* Drawings and Photographs

ABSTRACT

VARIOUS types of conveyors serviceable to the automotive industry are described, and consideration is given to the more important principles of selection and design. The general purposes of conveyors are first discussed; a method of planning the conveyor system for a given manufacturing process is then outlined and the common types of conveyor applicable to divers purposes are explained.

The strength, live-pin-bearing area and mass per unit of length vary with the kind of service. The design of sprockets to fit the chains with which they are to be used, the material of which they are composed and the number of teeth necessary to give evenness of service must be carefully considered. As the automotive industry almost always demands enormously greater service of a conveyor during part of its life than could be determined at the time of its installation, usually in the form of increased speed, the conveyor drive should be reasonably adjustable or quickly convertible to meet the possible demands.

Conveyors are classified into constant-speed and variable-speed. The latter are further classified into mechanical, electrical and hydraulic. Electrical variable-speed devices are divided into those that can be adjusted to give (*a*) continuous definite speed regardless of load, (*b*) continuous speed at constant load only or (*c*) definite travel regardless of load but with pulsating speed. Pulsating-speed control is obtained by a separate device. Views and descriptions of typical conveyor installations are included.

THE purpose of this paper is to describe various types of conveyor serviceable to the automotive industry, to consider the more important engineering principles of selection and design and to show drawings and photographs of some of the latest developments. In general, plants are conveyorized to give continuous coordinated and easily controlled flow of materials through the factory and yards; to use the more direct routes and levels not available to other means of transportation; to avoid much of the expense and loss of space due to the rehandling of products between operations; to avoid disagreeable handling of heavy, sharp, sticky, or hot materials; to time operations definitely without depending upon the vigilance of the attendant; sometimes to provide convenient temporary storage on the conveyor-line itself; and, in many cases, actually to do the work of operations such as dipping, feeding and agitating.

The plans for conveyorizing a given manufacturing process consist of listing the successive operations, with the respective rates of production and the spaces required; determining the suitable types of conveyor; planning to keep as many consecutive operations as possible on one conveyor without rehandling; considering the available buildings with a view to convenience and economy; and, finally, coordinating the system.

[1] Mechanical engineer, James F. Miller & Hurst Corporation, Detroit.

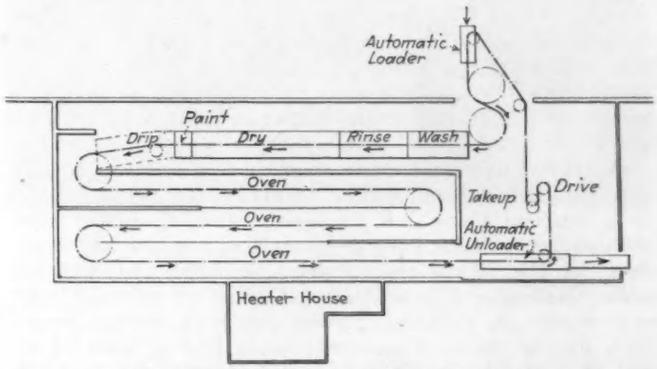


Fig. 1—Plan of Trolley-Type Conveyor with Automatic Loader and Unloader

Conveyors of this Type Are Used in Washing, Rinsing, Drying, Painting, and Baking Motor-Car Frames Weighing as Much as 300 Lb. It Allows Economy of Floor Space by Carrying the Frames on End and Close Spacing

Common types of conveyor adapted to the industry are: floor conveyors, to push lines of bodies; canvas and rubber-belt conveyors, to handle bulk materials, upholstery and packages; open wire-mesh-belt conveyors, for

Fig. 2—Automatic Loading Elevator

Adapter-Bars Are Piled at the Foot of the Elevator. These Adapters Are Pinned through the Frame Ends, and the Bar and Frame Are Pushed Forward on the Pile To Engage the Elevator

metal-parts washing-machines; trolley conveyors, for overhead delivery; double-strand conveyors, for dipping and drying and for bench-height assembling lines; drag flight conveyors, for raw bulk materials fed to numerous bins from the conveyor trough; gravity rolls, to move work between machines; wood and steel apron conveyors, to handle parts and boxes; and revolving platforms, to rotate groups of production machines in turn to the successive operators, when more than one operation is performed on a given machine.

CHAINS

Most of the power-driven conveyors mentioned above employ chains. The necessary conveyor-chain specifications vary, however. For example, a typical enameling conveyor requires chains having strength to take the load, large live-pin-bearing area to stand the wear at numerous bends and small mass per unit of length to absorb as little oven-heat as possible.

A typical monorail conveyor requires a chain capable of reasonable lateral flexure for traveling along curves in a vertical plane. A conveyor handling gritty substances must have a large protected pin-bearing area, mass at the joints and, perhaps, a large drag-surface area. Malleable or combination chains are good for general work. A steel-bar bushed chain is strong, wears well, can be made of accurate pitch and is adapted to rollers. A forged chain may be designed to be very strong and light, and may be made detachable and of few parts.

The sliding-friction coefficients of conveyor chains, either loaded or unloaded, when dragged on a horizontal steel-track without rollers or appreciable lubrication, is about 20 per cent of the vertical gross-load on the chain, when the chain is in motion.

Ordinary chain-rollers add life to the chain and give a coefficient of friction of about 15 per cent for 1½-in. rollers, and as low as about 6 per cent for 6-in. rollers with plain bearings. These figures vary greatly with the conditions. The starting load on conveyors may range from 50 to several hundred per cent above the normal running-load.

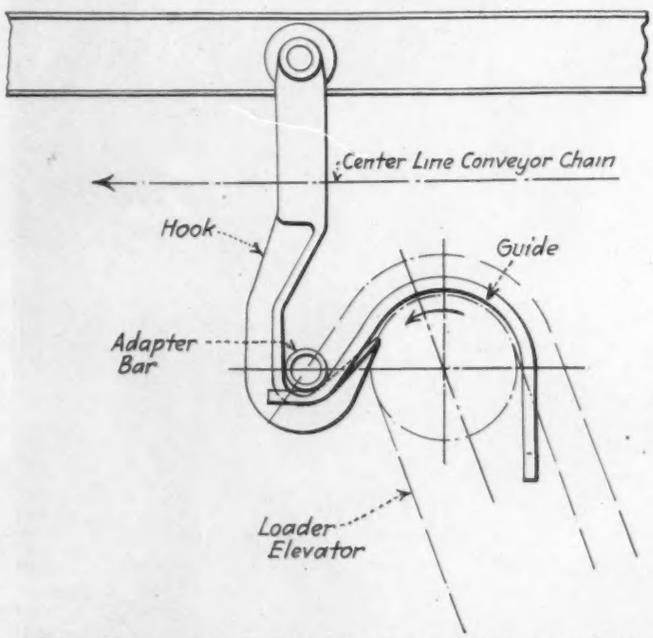


FIG. 3—DIAGRAM SHOWING THE ACTION OF THE AUTOMATIC LOADER ELEVATOR

The Bar Is Carried Over the Head Sprocket and Deflected from the Dog into the Hook by the Guide. The Hook Is Made Wide with a Modified V-Bottom To Line the Bar Athwart the Run of the Conveyor and Keep It Steady

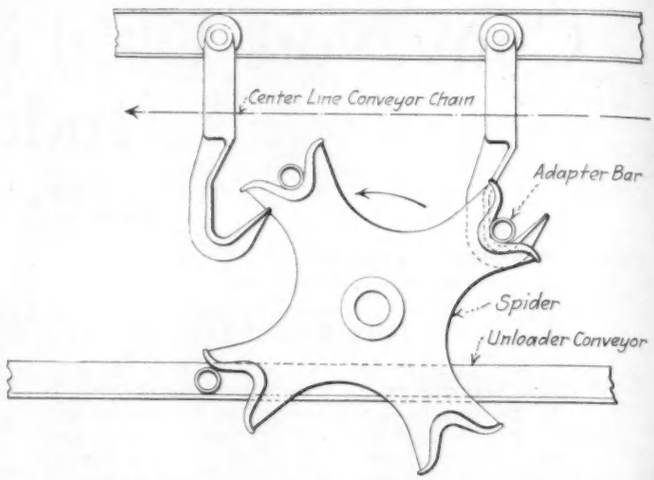


FIG. 4—DIAGRAM OF TRANSFER SPIDER ACTION BETWEEN THE FRAME CONVEYOR AND THE AUTOMATIC UNLOADER

The Transfer Spider Is Depositing One Bar on the Unloader Conveyor, Is Guiding Another Bar Past a Hook and Is Beginning To Lift a Third Bar. The Drive Is of the Mechanical Variable-Speed Type

Conveyor chains should probably never be run at a greater working-stress than 20 per cent of the ultimate strength, even at slow speeds and with heat-treated chains of high elastic-limit. The usual practice would be at a less stress, perhaps 10 per cent of the ultimate strength.

Designs should, when possible, give symmetry of attachment about the center line of the chain and of the conveyor to avoid eccentric loads. Automatic take-ups, to allow for the expansion and the contraction of long conveyors, may be of the gravity type, in which case the slack is taken up by a counterweighted carriage, or merely by the sag of the chain as it leaves the drive sprocket. The length of travel on a take-up should be somewhat greater than that sufficient to allow the removal of one unit length of chain.

Vertical and nearly vertical drive-chains operating on horizontal shafts should have tighteners. Horizontal drive-chains operating on horizontal shafts run best with the tight side on top. They then run freely on the sprockets, avoid kinks in the chain and prevent the interference of strands on long slack chains. If a chain reduction is used on vertical shafts, a tightener should be installed and the chain itself should run on guides.

SPROCKETS

Conveyor-chain sprockets usually have cast teeth. Sprockets must fit the chain, the chain being considered as the standard. Sprockets should be tested before shipment and checked before use, by wrapping a chain around their entire perimeters and examining them for fit. Slight imperfections on cast sprocket-teeth may usually be corrected by rough grinding.

When sprockets wear seriously, the root circle grows smaller, the chain settles into this smaller circle and the pin centers fall below the original pitch-circle. The chain is thus working on a tooth-spacing that is nearer the sprocket center and therefore shorter than the original chordal-pitch. Consequently, on a worn or short-pitch drive-sprocket, the chain first comes into contact toward the top of the tooth and slides down the side of the tooth. This action ruins both the chain and the sprocket.

Sprockets that have a deep chilled rim, or are steel castings, have about two and one-half times the life of plain cast-iron. When a conveyor uses two or more parallel strands of chain, all conveyor-chain drive-sprockets are keyed to the drive-shaft with the teeth in line, but only one sprocket on any one take-up or idler shaft is keyed to that shaft. This allows the other sprockets on that shaft to idle freely, and prevents one chain from taking more than its share of the load, when the strands are not perfectly matched.

Drive sprockets running at considerable speed should have 12 or more teeth to prevent shocks due to unevenness of drive. Very slow-speed drive-sprockets may run successfully with as few as six teeth. In many conveyors employing two strands of parallel chains and carrying loads suspended from spacer bars, as in the case of enameling ovens, through shafts would interfere with the hanging loads, and stub shafts must be used at the vertical bends. Some oven manufacturers require these stub shafts to be wholly within the oven to prevent loss of heat by conduction through the shaft. In such cases, the stub shafts are often held stationary and the sprockets are made to idle on roller-bearings.

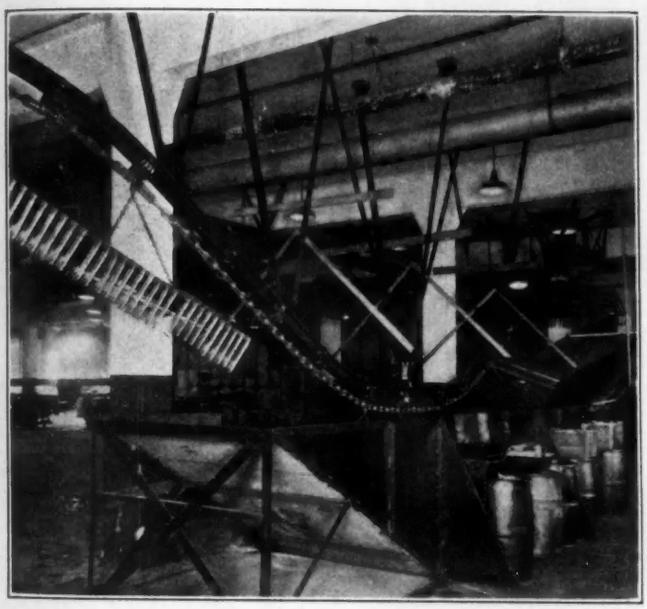


FIG. 5—MONORAIL CONVEYOR DIPPING WINDSHIELD FRAMES
This Particular Conveyor Is 1300 Ft. Long

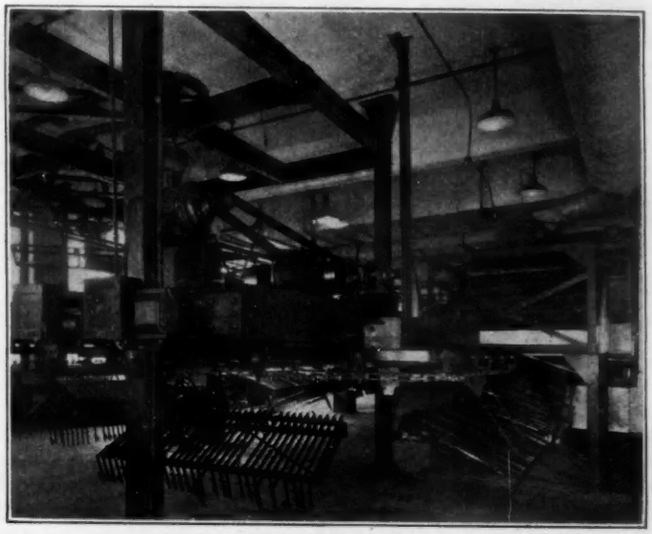


FIG. 6—DOUBLE DRIVE ON A MONORAIL CONVEYOR
The Large Sprocket-Wheel at the Left on the Elevated Run and the One below the Motor Are Drivers. The Double Drive Approximately Halves the Maximum Chain-Pull That Would Have Resulted from a Single Drive

Roller-bearing idlers run best without lubrication above 600 deg. fahr. and require very little attention. They can stand temperatures up to 800 deg. fahr., but the bearings should be installed with the end and bore clearances specified for a particular temperature by the bearing manufacturer.

DRIVES

The automotive industry almost always demands enormously greater service of a conveyor during a part of its life than could be determined at the time of its installation. Usually this demand is in the form of in-

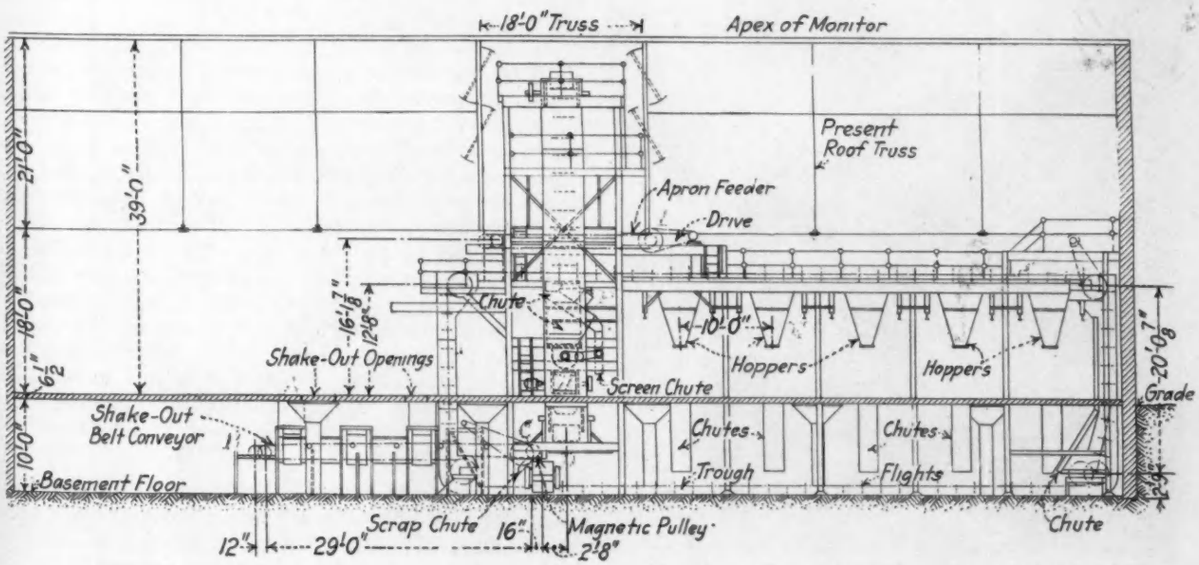


FIG. 7—ELEVATION OF A TYPICAL SAND-CONVEYOR SYSTEM ADAPTED TO A GRAY-IRON ENGINE-CASTING FOUNDRY
Molds Are Shaken Out on the Main Floor over Grates. The Castings Are Conveyed or Trucked Away, While the Sand Falls to a Shake-Out Belt or Steel Apron-Conveyor and Passes over a Magnetic Head-Pulley To Remove the Steel and Iron Scrap

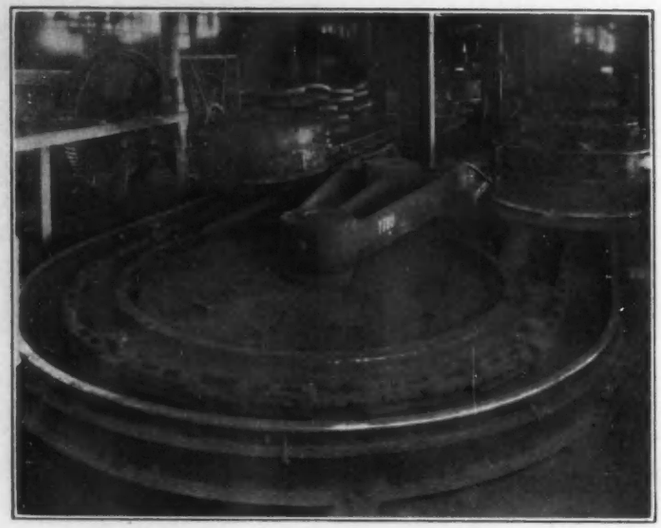


FIG. 8—TAKE-UP END OF HEAVY-TYPE MOLD-CONVEYOR HANDLING TRACTOR-WHEEL MOLDS
The Conveyor Receives Tractor-Wheel Drags, Cores and Copes and Then Takes the Molds through the Pouring-Station and over the Cooling-Run Back to the Shake-Out

creased speed of travel. In the case of oven conveyors, the time in the oven tends to determine the speed of the conveyor, but the oven-time principle, nevertheless, is often violated when production requires it to be. Consequently, a conveyor drive should be reasonably adjustable or quickly convertible to the possible demands of speed.

Increased conveyor-speed in itself does not mean appreciable increase of torque, so that most conveyors are strong enough to stand considerable speeding-up, but, of course, with a consequent sacrifice in the life of the conveyor. Greatly increased speed will require correspondingly increased driving-power and often a larger motor.

Drives may be classed as constant-speed and variable-speed. An economical constant-speed drive for a heavy slow-speed conveyor with horizontal drive-shaft consists of a motor directly connected to an enclosed gear-reducer with a roller-chain reduction to the head-shaft through a shear-pin.

A reducer and chain reduction in series is considered more economical than a high-ratio reducer and a large flexible coupling on the head-shaft. The chain reduction is a flexible connection in itself and allows the motor and reducer to be located at any one of several positions relative to the drive-shift. It is also more economical to change sprockets than reducers, if an alteration of speed is ever required. The arrangement allows the adoption of fewer stock ratios for reducers. For vertical shafts, the final reduction may be through an angle-reducer and spur-gears or a chain.

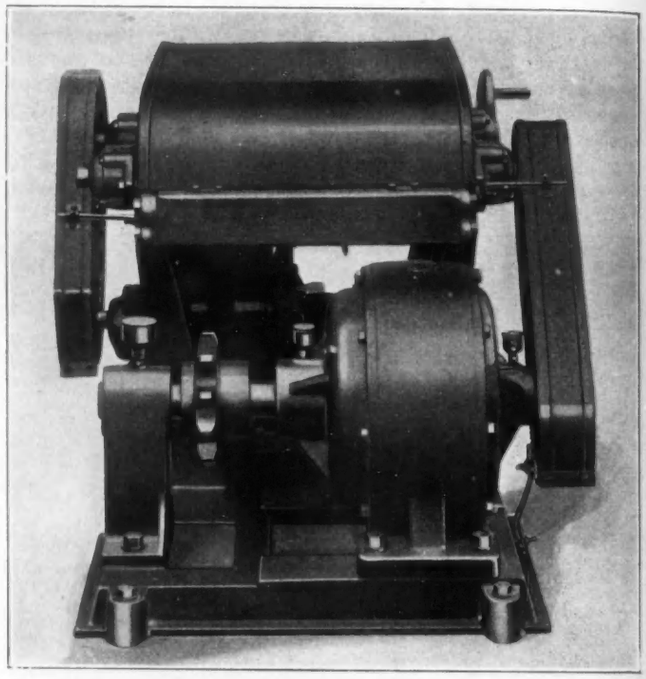


FIG. 10—SLOW-SPEED END OF VARIABLE-SPEED DRIVE
This Is Another View of the Unit Shown in Fig. 9

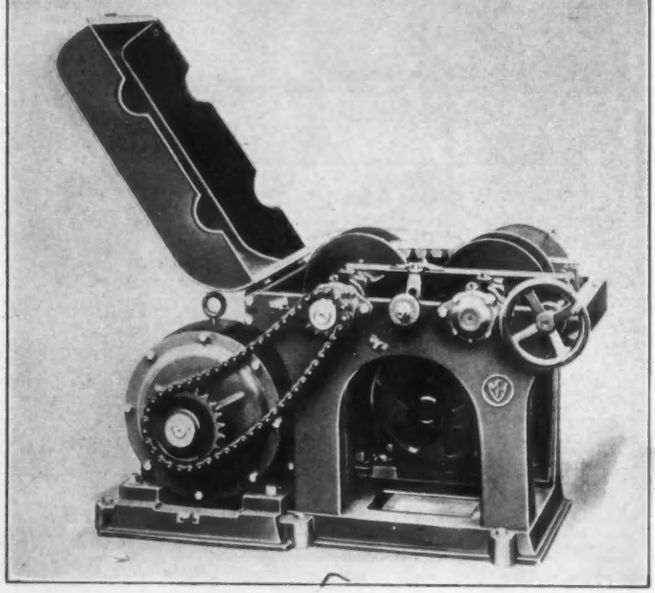


FIG. 9—VARIABLE-SPEED DRIVE BUILT AS A SELF-CONTAINED UNIT
The Top Guard Has Been Lifted To Expose the Mechanical Variable-Speed Transmission

On heavy drives using a sprocket on the low-speed shaft of the reducer, an outboard bearing is often necessary or advisable. This outboard bearing should be mounted on the same cast-iron base, or on the same heavy structural member, as the reducer. Even enormously strong carefully designed steel-structures show weave when heavy-duty machinery is running on them, and every care must be taken not to allow any chance of misalignment of the bearings. Flexible couplings take care of some misalignment between the shafts. Chain reductions take care of even greater misalignment.

The shear-pin is more nearly certain of effect when installed at the slow-speed end of the reduction-train, since the inertia of high-speed members might be sufficient to wreck the conveyor even after the pin had actually sheared.

CONTROL

Remote-control push-buttons should be placed at strategic points to stop a conveyor instantly should occasion demand. Limit switches should be used when they may prevent injury to men or property. A simple form of safety-switch is a wire stretched across an open

space and arranged to pull a switch in case a man or an object should be drawn into danger.

Variable-speed drives may be classed as mechanical, electrical and hydraulic. The mechanical variable-speed transmission most used is of the Lewellen or the Reeves type and consist of a belt running over adjustable pulleys that virtually change the ratio of the diameters. Adjustment of speeds near zero cannot be obtained, but ratios between the highest and the lowest speeds obtainable on some models of this type are as great as 8 to 1. This type of variable-speed transmission is very useful and dependable and is adaptable to most conditions.

FIG. 11—HEAD END OF A TYPICAL FLOOR-TYPE BODY-CONVEYOR
The Bodies Are Carried on Low Trucks to Which They Are Clamped and Which Straddle the Conveyor Chain. The Drive in This Case Has Been Installed on the Floor But Could As Well Have Been Hung beneath the Floor out of the Way

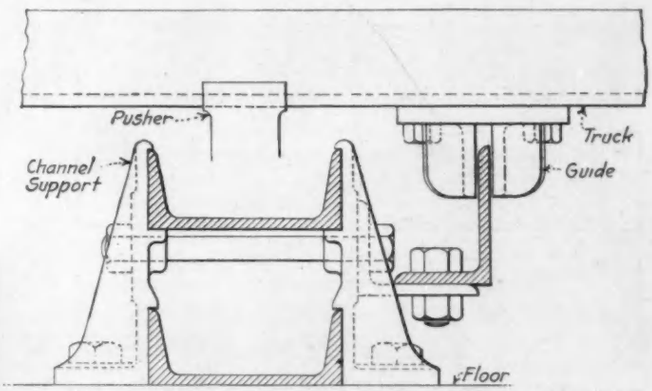


FIG. 12—CROSS-SECTION OF FLOOR-TYPE BODY-CONVEYOR
The Chain Runs Over the Top Channel and Pushers Engage the Body Trucks. The Chain Returns on the Lower Channel, the Pushers Having Deflected to a Level Position

The electrical variable-speed devices may be divided into those that can be adjusted to give (*a*) continuous definite speed regardless of load, (*b*) continuous definite speed at constant load only or (*c*) definite travel regardless of load but with pulsating speed. The first may be an adjustable-speed motor, such as the three-phase squirrel-cage motor having the stator specially wound to be connected in as many different manners as there are speeds on the control. Three and four-speed motors are commonly used. No speeds between these definite adjustments are obtainable with this type of motor. This variable-speed motor is useful when accurate adjustments and timing are not necessary and when safety demands direct coupling, as on a continuous body-lowerator.

The pulsating speed-control is a separate device from the conveyor motor and changes the motor-speed from full to fractional or even to a stop, during adjustable periods of a minute, to give any average speed desired between full speed and zero. This variable-speed pulsating-control is more expensive than the common size

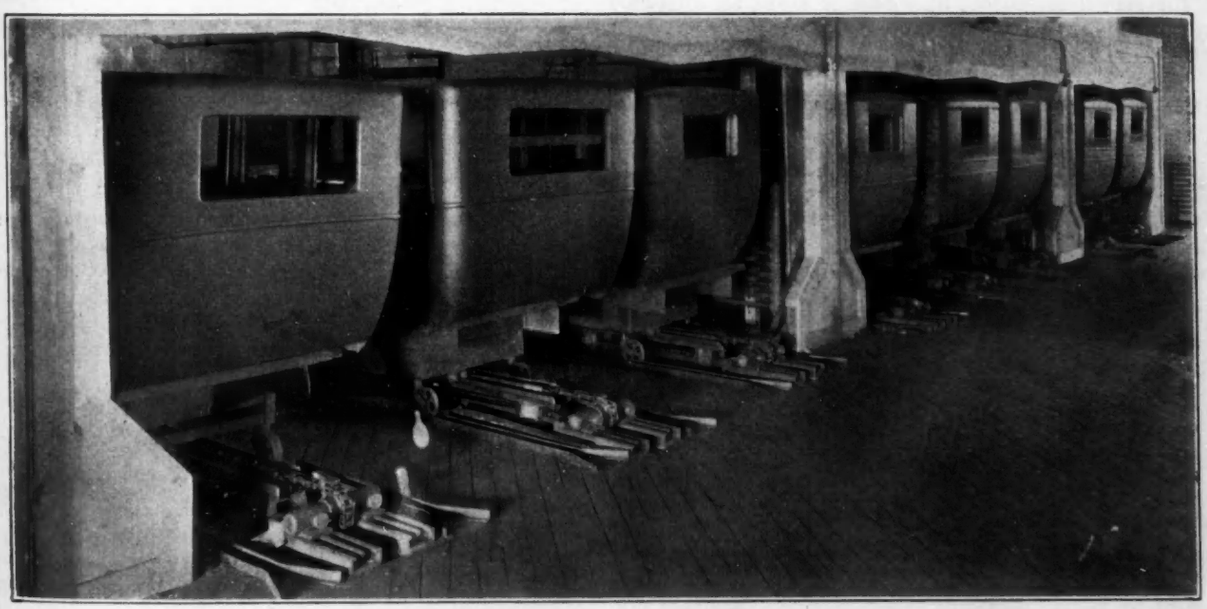


FIG. 13—LOADING END OF BODY CONVEYORS
Guides on the Trucks and Bell-Mouthed Channel Caster Tracks Steer the Trucks on to the Guide Angles

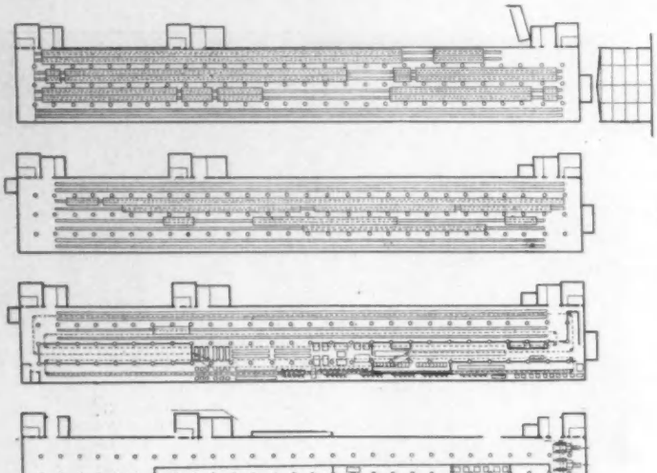


FIG. 14—PLAN OF CONVEYOR LAYOUT OF A MODERN BODY-FINISHING PLANT
The Steel Bodies Are Received on the Railroad Dock and Are Clamped to the Body Trucks, Which Are Handled between Floors on Continuous Body-Elevators. Starting on the Top Floor, the Bodies Are Run through the Finishing Processes on Special Floor-Type Conveyors

of mechanical control, when one conveyor only is in question, but becomes economical when one control only may handle more than one conveyor of a coordinated system and is considered useful when unevenness of speed is not objectionable.

CONVEYORS USED AS PACE-MAKERS

Conveyors are used in some plants as pace-makers in production. In at least one such plant, variable-speed drives are adjusted on all conveyors to give a definite balanced day's output. The respective drive-adjustments are then locked into place, and the conveyors are kept at capacity. The scheme seems to be very satisfactory.

The hydraulic transmission, using oil as the transmission medium, has been extensively used by the Government for the training of heavy guns. One maker recommends such a transmission for industrial use, except for very low speeds, at which it gives an unsteady drive on his particular transmissions. This type of transmission has the advantage of allowing one or more driven ends to be run at various places, all from one pump-end. If, however, several conveyors are run from such individual drives connected to one pump-end, and their speeds are coordinated by simple throttle-control, this coordination of speeds will not remain constant on the same adjustment, if the ratios of the loads on the conveyors are changed. All hydraulic transmissions are necessarily made with nearly perfect fits, and several high-grade machines are on the market. At present, however, these machines are expensive and, if repairs are necessary, are beyond the capacity of the ordinary plant-maintenance department.

A typical mechanical variable-speed conveyor-drive consists of a motor running at about 1160 r.p.m., a silent-chain reduction to a variable-speed transmission of the Lewellen or the Reeves type with a constant-speed shaft at about 350 r.p.m., a flexible coupling to an enclosed gear-reducer, and a final roller-chain reduction through a shear-pin. The reduction from the motor to this type of variable-speed transmission has proved necessary for the well-being of the transmission belt. The above arrangement is very satisfactory.

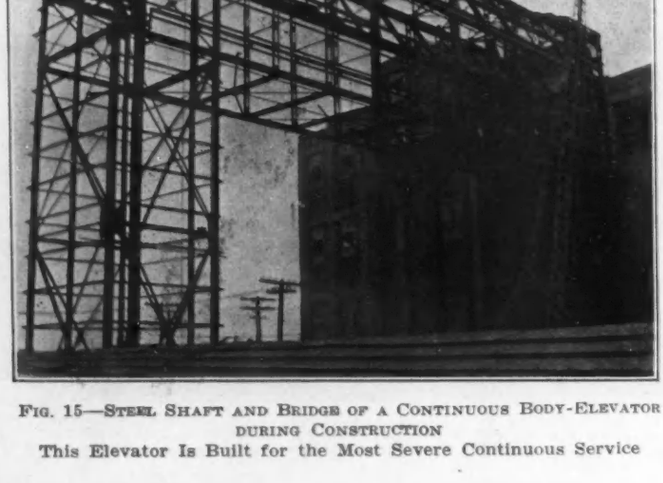


FIG. 15—STEEL SHAFT AND BRIDGE OF A CONTINUOUS BODY-ELEVATOR DURING CONSTRUCTION
This Elevator Is Built for the Most Severe Continuous Service

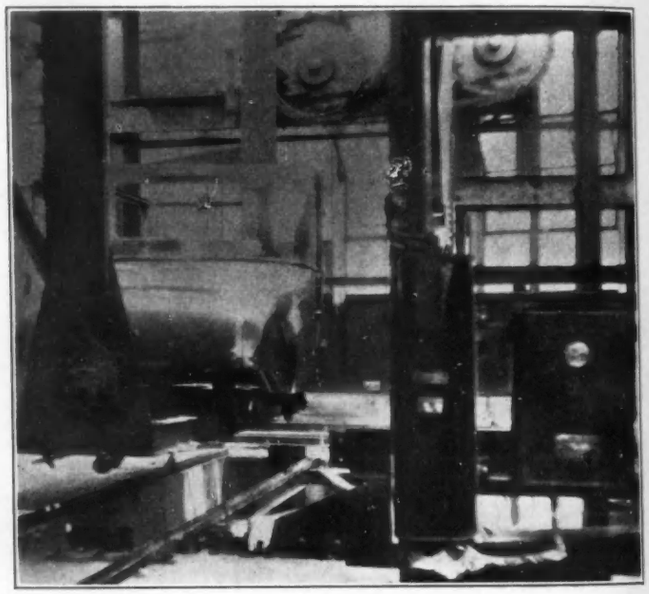


FIG. 16—LOADING END OF CONTINUOUS BODY-ELEVATOR
The Sling Has Just Lifted a Body and a Truck from the Tracks

TYPICAL CONVEYOR INSTALLATIONS

Fig. 1 shows the plan of a trolley conveyor with automatic loader and unloader, used in washing, rinsing, drying, painting, and baking motor-car frames weighing as much as 300 lb. each. This monorail-type conveyor was chosen to give economy of floor space by carrying frames on end and, by using 8-ft. sprockets at the bends, to allow close load-spacing.

The features of this conveyor are:

(1) The use of adapter-bars to make all the various models of frames uniform for attaching to the conveyor
(2) A high-speed two-strand continuous elevator with dogs timed to hoist the frames about 20 ft. into the conveyor-hooks
(3) The main conveyor proper
(4) A transfer to lift the frames from the hooks
(5) A conveyor to lower the frames from the transfer to a convenient platform

Fig. 2 shows the loading end of the conveyors, with

the automatic loading-elevator and adapter-bars piled at its foot. These adapters are pinned through the frame ends, and the bar and frame are pushed forward on the pile to engage the elevator.

Fig. 3 shows the action of the elevator. The bar is carried over the head sprocket and deflected from the dog into the hook by the guide. The hook is made wide with a modified V-bottom, to line the bar athwart the run of the conveyor and keep it steady.

Fig. 4 shows the transfer spider depositing one bar on the unloader conveyor, guiding another bar past a hook and beginning to lift a third bar. The drive is of the

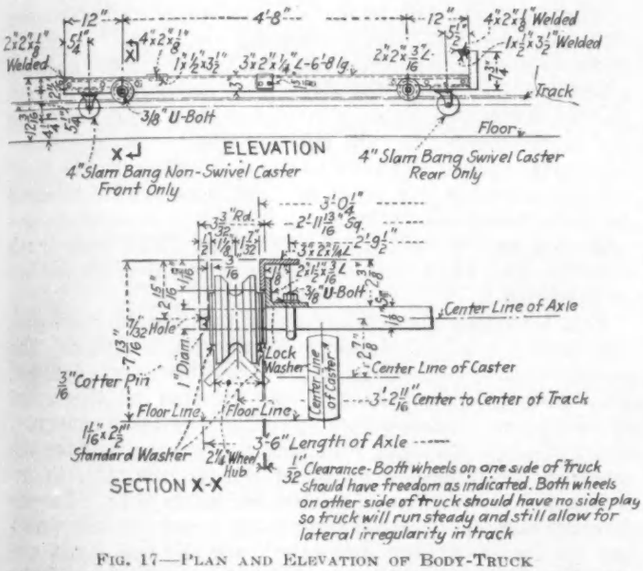

ELEVATION
4" Slam Bang Non-Swivel Caster Front Only
4" Slam Bang Swivel Caster Rear Only
3/8" U-Bolt
Track
Floor
SECTION X-X
Center Line of Axle
Center Line of Caster
Center to Center of Track
Length of Axle
Lock Washer
Standard Washer
Clearance-Both wheels on one side of truck should have freedom as indicated. Both wheels on other side of truck should have no side play so truck will run steady and still allow for lateral irregularity in track

FIG. 17—PLAN AND ELEVATION OF BODY-TRUCK

This Truck Runs upon Casters, When Off the Conveyor, and upon Auxiliary Grooved Wheels, When On the Conveyor. The Truck Shown Is Intended To Run Over Conveyors Having Level Tracks

mechanical variable-speed type. The conveyor chain has an ultimate strength of 125,000 lb. The normal capacity of the conveyor is about 240 frames, or about 60,000 lb. of frames per hr. At this rate, with four men to load, four to haul the frames away from the unloading platform, one to attach and remove the adapters, and one or two to look after the painting and other operations of the system, the labor has been reduced to less than 0.05 man-hr. per frame. Formerly, a large corps of men was required to perform the operations now performed by the conveyor; and production was seriously hampered by a constant congestion of frames in process.

Fig. 5 shows a 1300-ft. monorail conveyor dipping windshield frames.

THE DOUBLE DRIVE

Fig. 6 shows the double drive. The large sprocket-wheel at the left on the elevated run and the one below the motor are drivers. After leaving one of these drivers, the conveyor travels about one-half its length before returning to engage the second driver. This double drive approximately halves the maximum chain-pull that would have resulted from a single drive.

Fig. 7 shows a typical sand-conveyor system adapted to the gray-iron engine-casting foundry. Molds are shaken out on the main floor over grates. The castings are conveyed or trucked away, while the sand falls to a shake-out belt or steel apron-conveyor and passes over a magnetic head-pulley to remove the steel and iron scrap. The sand is then elevated by the vertical run of the flight delivery conveyor and is passed through the screen, mixer and beater. It is then elevated by a second flight-

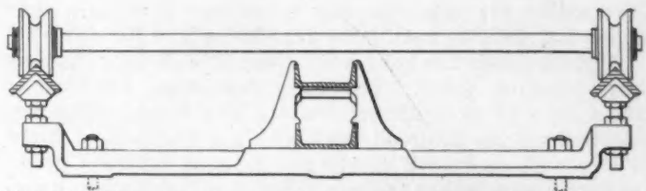


FIG. 18—CROSS-SECTION OF SPECIAL FLOOR-TYPE BODY-CONVEYOR HAVING TRACKS THAT ARE ADJUSTABLE FOR LEVEL

The Contract Specified a Normal Conveyor-Speed of About 2 Ft. per Min., But a Few Months Later the Customer Demanded a Speed of 32 Ft. per Min., To Increase the Plant Capacity to 800 Bodies in 9 Hr. The Conveyors Worked Perfectly at the Increased Speed

conveyor to a tempering-bin, from which it is fed by a steel apron-feeder to the flight delivery conveyor, which distributes it to the hoppers over the molding-machines.

Fig. 8 shows a heavy-type mold-conveyor, which receives tractor-wheel drags as it passes the molding-machines, cores at a core-setting station and the copes at the cope machine where the molds are closed. The conveyor then takes the molds through the pouring-station and over the cooling-run back to the shake-out. The empty flasks are there returned to the conveyor to be distributed again to the molding-machines. The capacity of a given foundry building is increased enormously by such equipment. One very successful foreign firm planned a 300 x 500-ft. foundry with sand-handling and conveying machinery for its own gray-iron engine-castings. Figures showed that a 100 x 300-ft. foundry would have at least an equal capacity, if equipped with American conveyor-systems.

Fig. 9 shows a typical variable-speed drive built as a self-contained unit. The lifted top-guard exposes the mechanical variable-speed transmission.

Fig. 10 shows the low-speed end of the same unit with drive-sprocket.

FLOOR-TYPE BODY-CONVEYOR

Fig. 11 shows the head end of a typical floor-type body-conveyor. Note that the bodies are carried on low trucks to which they are clamped. These trucks straddle the conveyor-chain. Also note the drive-sprocket and the head-shaft. The trucks run on swivel casters over 3/16 x 5-in. flat steel tracks. The drive in this case has been installed on the floor but could as well have been hung beneath the floor out of the way.

Fig. 12 shows a cross-section of this body-conveyor. The chain runs over the top channel, and pushers engage the body trucks. The chain returns on the lower channel, the pushers having deflected to a level position. The patent supports clamp the structural-steel channels at 5-ft. intervals and act both as supports and as fish-plates at the channel splices. The channels need not be punched or drilled, and the conveyor can be quickly installed or quickly dismantled and shipped, should circumstances require. The trucks can be most easily handled on swivel casters, when off the conveyor, but these casters make a very unstable job for working on the bodies, so, the trucks are made steady by running a structural-steel guide-angle the whole length of the conveyor and installing guides at both ends of the trucks to engage this angle.

Fig. 13 shows the loading end of several parallel body-conveyors. Note the guides on the trucks and the bell-mouthed-channel caster-tracks to steer the trucks on to the guide-angles. This particular installation is in a plant that has recently been almost completely conveyorized. The conveyors have substantially decreased the pay-roll and have increased the output at least 200 per cent with the same floor-space. These conveyors made

it possible for this company to execute contracts that could not possibly have been handled by the old methods.

Fig. 14 shows the conveyor layout of a strictly modern body-finishing plant. The main four-story building is 100 x 700 x 18 ft. between floors. The steel bodies are received on the railroad dock and are clamped to body trucks. These loaded trucks are handled between floors on continuous body-elevators. Starting on the top floor, the bodies are run through the finishing processes on special floor-type conveyors. A 36-in. x 600-ft. belt-conveyor takes upholstery from the sewing-machines. Overhead-trolley conveyors distribute tops, trim, windshields, seats, and the like to the body lines. Seat trimming is done on a continuous buck-conveyor.

Construction Details

Fig. 15 shows a view of the steel shaft and bridge of the first-to-the-fourth-floor continuous body-elevator during construction. This elevator is built for the most severe continuous service. Body slings are hung from two strands of steel-bushed chain. The shaft and bridge steel weighs about 75 tons. The drive consists of a four-speed squirrel-cage motor fitted with a solenoid brake and direct connected to an enclosed spur-gear reducer, an open spur-gear reduction to a 4 15/16-in. countershaft and parallel spur-gear reductions to the two stub head-shafts. The long countershaft is built heavy to prevent vibration. The drive is mounted on a cast-iron base-plate with an outboard bearing for the reducer and a center bearing for the countershaft. The design was carefully worked out with a view to safety and endurance for both the elevators and the lowerators. Variable-speed squirrel-cage motors were chosen as the safest, both to drive and to retard, and their range of speed was acceptable. Belts and drive-chains were eliminated as unsafe.

To prevent a sling from being lowered onto a body that might not have been removed, two limit-switches are mounted on the elevator frame and connected in parallel. When a body is lowered on to the unloading tracks, it opens one of these limit-switches. When a sling reaches a position near the unloading point, it opens the other switch. Consequently, if a body remains too long at the unloading position, both switches are opened and the conveyor is stopped before damage occurs.

Fig. 16 gives a view of the loading ends, the sling having just lifted a body and a truck from the tracks. Note that the sling passes through the inside track, part of which is necessarily supported from that portion of the frame about which the sling passes. Note the gravity stub-shaft take-up. The lowerators are similar in construction to the elevators but operate in the opposite direction and have the limit-switches at relatively different stations.

The Body-Truck

Fig. 17 shows the body-truck. This truck runs upon casters, when off the conveyor, and upon auxiliary grooved-wheels, when on the conveyor. The grooved wheels on one side of the truck have no lateral clearance, so that, when they engage the inverted V-rails, they hold the body firmly to prevent side-play. Some manufacturers employ body-trucks that are exceedingly rigid and use them as a correct surface from which to hang doors. Others use light inexpensive trucks and depend upon bracing to hold the bodies true. The body-truck shown in Fig. 17 is intended to run over conveyors having level tracks.

Fig. 18 shows a cross-section of this special conveyor. The tracks are adjustable vertically for leveling. The conveyor chains run in the usual structural-steel channels. This body-finishing plant is an example of the usual speeding-up. The contract specified a normal conveyor-speed of about 2 ft. per min., but a few months later the customer demanded a speed of 32 ft. per min. to increase the plant capacity to 800 bodies in 9 hr. Larger drives and motors were installed, the conveyors are working perfectly at the increased speed, and they are handling the enormously greater output with very slight increase in overhead expense. Should it be desired to find the saving effected by a given conveyor-installation, the use of Formulas for Computing Economies of Labor-Saving Equipment, by a committee of the Materials-Handling Division of the American Society of Mechanical Engineers, may be applied to find this saving in financial terms.

AMERICA'S SHARE IN WORLD TRADE INCREASING

A COMPARISON of the foreign trade of the United States with that of other countries shows that our share in the world's international commerce has increased in recent years. The Department of Commerce recently announced that American exports and imports of merchandise in 1925 comprised 15.6 per cent of the combined foreign trade of 55 countries, representing about nine-tenths of the world's commerce. This compares with 12.9 per cent in 1913, the year before the war.

The report indicates that the world's physical volume of trade last year equaled the pre-war total for the first time since the close of the war. The monetary value of the trade of the 55 countries last year was $58,500,000,000 as against $51,600,000,000 in 1924 and $37,900,000,000 in 1913. Last year's total is 13.4 per cent larger than that of the preceding year and 54.3 per cent above that of the last pre-war year. The gain over 1924 is partly, though not entirely, due to the higher price levels that prevailed last year. The increase since 1913 is believed to be almost wholly due to higher price levels, so that the physical volume of trade may be regarded as approximately equal to that which was carried on before the war.

The largest increase in exports since 1924 was achieved by Germany. British Malaya scored the second largest gain, followed in order by the United Kingdom, United States, British India, Canada, Japan, Australia, and Italy. Germany also led in import expansion, with the United Kingdom, United States, British Malaya, Italy, Argentina, Russia, and Brazil following in the order named.

That the greatest expansion of foreign trade should be found in the European countries in which economic recovery progressed most rapidly during the year is natural; and the same tendency may reasonably be expected to continue for some time to come. With the continued revival of European trade, the share of the United States, in percentage terms, will hardly remain as large as it was last year. This does not mean, however, that the absolute value or volume of our trade is likely to decline. On the contrary, European recovery should have the effect of stimulating American foreign trade as a whole.—*Guaranty Survey.*

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Inspection of Knight Engine-Sleeves

By J. B. Scott[1]

Production Meeting Paper *Illustrated with* Photographs and Drawings

ABSTRACT

TO many engineers, even to those who are familiar with the operations involved in the building of poppet-valve engines, the control of the details of production and of inspection of Knight engine-sleeves presents novel features of interest, and these are outlined by the author. After illustrating the rough and the finished sleeve, he exhibits the microstructure of the metal used and states the physical properties desired.

The "normalizing" process for the removal of casting strains and the method used for determining the hardness of the sleeves are mentioned, together with a statement of the tolerances that are allowed, and the finish-boring operation is described as a means of conveying an impression of inspection requirements. Many details of inspection are then enumerated.

INSPECTION details of the operations involved in the production of the sleeves which are essential parts of the Knight-engine valve-mechanism should be of interest to engineers, even though they be familiar with the production and the inspection operations involved in the building of poppet-valve engines, since there are relatively few builders of Knight engines in the United States and these details are not known generally.

Fig. 1 shows a Knight engine-sleeve in both the rough and the finished form. The sleeve illustrated is used in a 4¼ x 5½-in. six-cylinder engine and, as it comes from the foundry, the casting weighs 19 lb.; but the weight of the finished sleeve is only 8 lb.

The microstructure of the metal used in these sleeves is shown in Fig. 2, magnified approximately 70 diameters. It will be observed that the graphitic distribution is good, and that there is an absence of large graphitic segregations. The iron is of dense structure and has good physical properties. The physical properties desired are as stated in the analysis that accompanies Fig. 2.

All sleeve castings are "normalized" to remove casting strains. One of the car-type annealing-furnaces used for this operation is illustrated in Fig. 3. The sleeves shown have been rough-bored and rough-turned before normalizing, but it is our present practice to normalize the sleeves in the condition in which they are received from the foundry. The normalizing operation takes place in a 12-hr. cycle, the temperature being gradually increased to 1060 deg. fahr., and this temperature is then maintained for a 3-hr. period. It will be understood that the furnace temperature is always well below the annealing range. In actual practice, the hardness of the sleeves is reduced only about 1½ points, Rockwell, in the normalizing operation.

Method of Measuring Hardness

After extensive experimentation with various means for measuring hardness, the Rockwell instrument shown in Fig. 4 has been adopted. By this method we obtain uniform results and are able to handle our testing rapidly. The hardness tolerance is 90 to 95 Rockwell. We are convinced that there is no consistent relationship between the hardness of a gray-iron casting, as determined by any method with which we are familiar, and machinability or resistance to wear. It is our belief that we can control sleeve castings only by consistently checking the analysis of the physical properties and the microstructure, in addition to controlling the hardness.

Examination of the detailed drawing of the sleeve shown in Fig. 5 discloses several close tolerances and the fact that a considerable number of machining operations are involved in finishing the sleeves. Inside and outside diameters are held within 0.0005 in. Sleeves are permitted to taper within the diameter tolerance only. The maximum out-of-round tolerance is 0.004 in. at the upper end of the sleeve, and 0.002 in. at the lower end. The distance from the center of the sleeve pinhole to the lower edges of the ports is held within 0.004 in. The width of the ports is held within 0.002 in.

Finish-Boring Operation

No attempt is made in this paper to describe manufacturing operations except incidentally and as a means of conveying an impression of inspection requirements. From this viewpoint, the finish-boring operation is of interest. This operation is performed after the sleeve

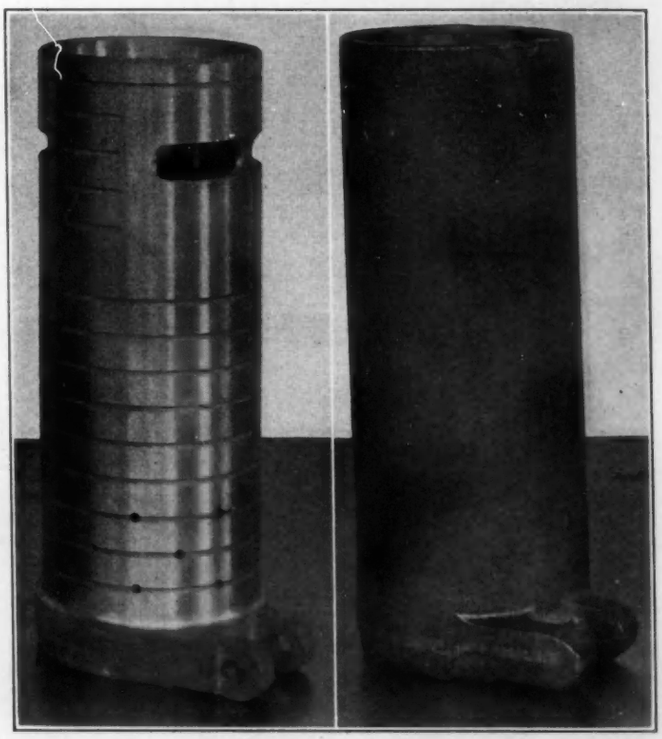


Fig. 1—Knight Engine-Sleeves
The Rough Casting, Weighing 19 Lb., Is Shown at the Right and the Finished Sleeve, Weighing 8 Lb., Appears at hte Left. The Sleeve Illustrated Is for a 4¼ x 5½-In. Six-Cylinder Engine

[1] M.S.A.E.—Chief inspector, Yellow Sleeve Valve Engine Works, Inc., East Moline, Ill.

FIG. 2—MICROPHOTOGRAPH OF THE METAL USED FOR KNIGHT ENGINE-SLEEVES

The Structure Is Magnified Approximately 70 Diameters. The Graphitic Distribution Is Good, and Large Graphitic Segregations Are Absent. The Iron Is of Dense Structure and Has the Following Physical Properties:

	Per Cent
Total Carbon	3.09
Graphitic Carbon	2.49
Combined Carbon	0.60
Silicon	2.20
Nickel	1.40
Chromium	0.11
Sulphur	0.09
Phosphorus	0.17

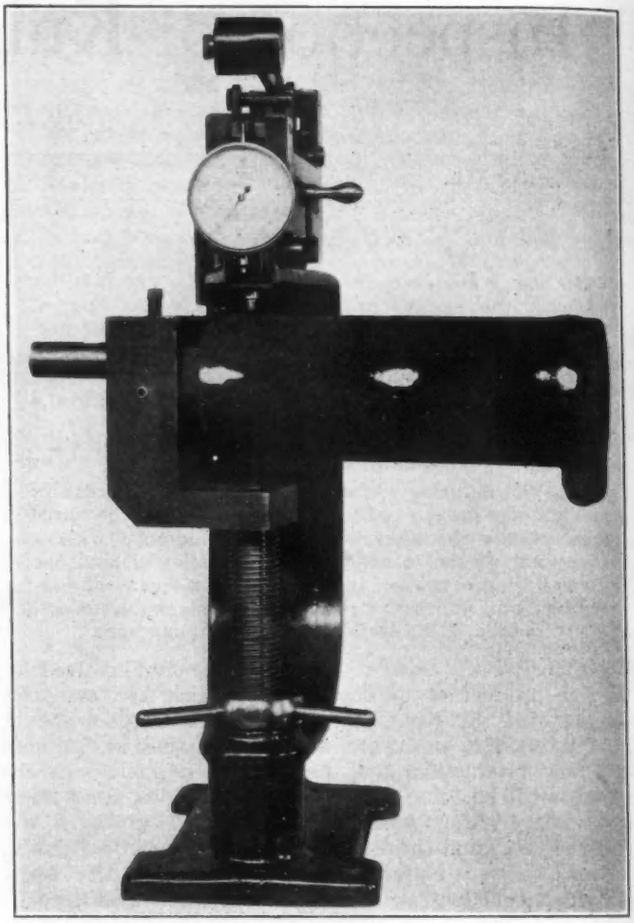


FIG. 4—ROCKWELL INSTRUMENT FOR MEASURING HARDNESS

Uniform Results Are Obtained with This Instrument and the Testing Can be Done Rapidly. The Hardness Tolerance Is 90 to 95

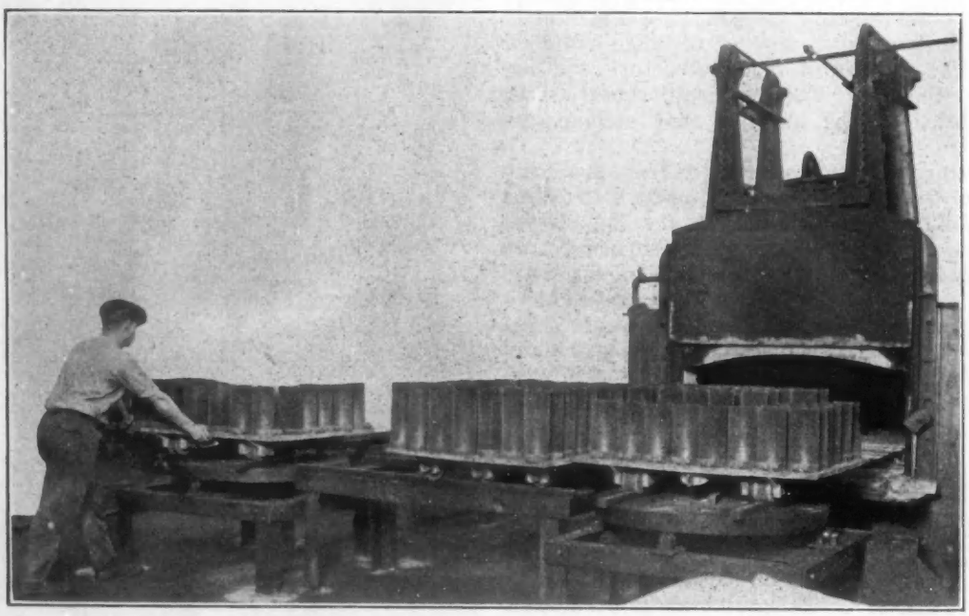


FIG. 3—CAR-TYPE ANNEALING-FURNACE

The Removal of Casting Strains Is Accomplished in the Type of Furnace Shown, the Process Being Known as "Normalizing." The Sleeves Are Normalized in the Condition in Which They Are Received from the Foundry, Throughout a 12-Hr. Cycle in Which the Temperature Is Increased Gradually to 1060 Deg. Fahr. and Maintained at That Value for 3 Hr. The Furnace Temperature Is Always Maintained Well Below the Annealing Temperature-Range

has been rough-bored, rough-turned, centered, and finish-turned. It will be noted from Fig. 6 that the finish-boring chuck is water-cooled. By water-cooling the sleeve while it is undergoing the finish-boring operation, the temperature rise resulting from the heat due to the cut is kept low enough to prevent any considerable taper in the bore of the sleeve when it cools after this operation. Care exercised in this operation reduces the total amount of metal which must be removed from the sleeve-bore in the grinding operations to the minimum. To establish close contact between the sleeve and the water-cooled walls of the chuck, the finish-turning operation is held within a tolerance of 0.001 in.

To maintain a tolerance of 0.004 in. in a length of almost 10 in. requires care in the control of temperature. These are conditions which are encountered in the milling of the ports, which is illustrated in Fig. 7. Relatively small temperature-changes affect the fixture, the cutter arbors, the work arbors, and the milling-machine itself to a considerable degree, in relation to the tolerance

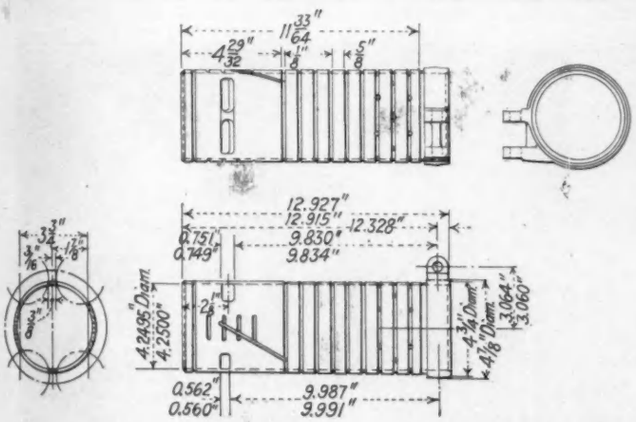


FIG. 5—DETAILS AND TOLERANCES OF KNIGHT ENGINE-SLEEVES

The Drawing Discloses Several Close Tolerances and the Fact That a Considerable Number of Machining Operations Are Involved in Finishing the Sleeves. Inside and Outside Diameters Are Held within 0.0005 In. Sleeves Are Permitted To Taper within the Diameter Tolerance Only. The Maximum Out-of-Round Tolerance Is 0.004 In. at the Upper End of the Sleeve, and 0.002 In. at the Lower End. The Distance from the Center of the Sleeve Pinhole to the Lower Edges of the Ports Is Held within 0.004 In. The Width of the Ports Is Held within 0.002 In.

which must be maintained in the porting operation. One precaution taken in connection with this operation is to run the machine light until the approximate working-temperatures have been reached before the actual operation of porting is started.

INSPECTION DETAILS

Immediately following this porting operation, the sleeves are given a complete inspection as to the relation of port edges to sleeve pinhole, width of ports, diameters, oil-hole drilling, oil-grooving, and the grinding relief. Extensive use is made of indicators in connection with reference-gages to which the indicators are set, as illustrated in Fig. 8. This method of measurements has been found most satisfactory because the indicators cannot be forced, accurate measurements can be made by unskilled workmen, accuracy of measurement is not affected by rapid gage-wear, and the cost of maintaining gages is fairly low. The reference-rings, the blocks and the height-blocks, to which the indicators are adjusted, are inspected and checked once each week by means of Johansson gages. Temperature variations must, of course, be reduced to the minimum in all these gaging and checking operations.

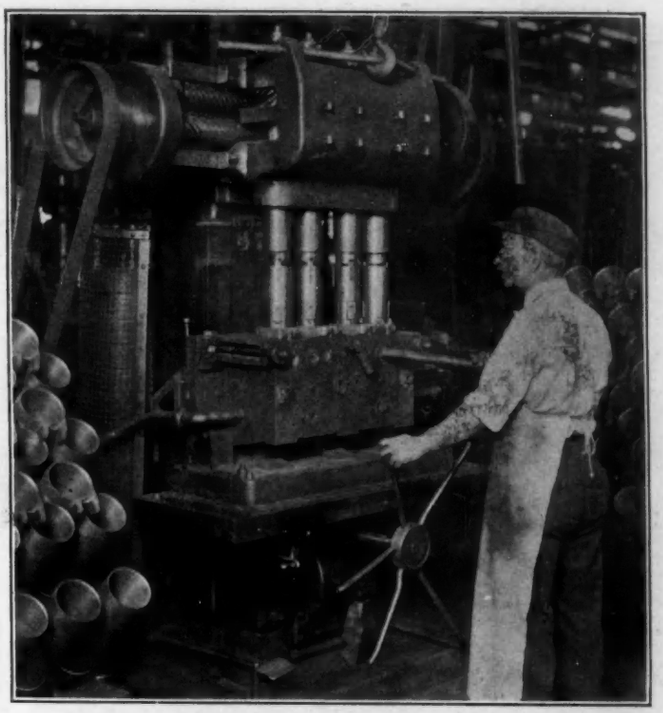


FIG. 6—THE FINISH-BORING OPERATION

This Operation Is Performed after the Sleeve Has Been Rough-Bored, Rough-Turned, Centered, and Finish-Turned. The Finish-Boring Chuck Is Water-Cooled. By Water-Cooling the Sleeve While It Is Undergoing the Finish-Boring Operation, the Temperature Rise Resulting from the Heat Due to the Cut Is Kept Low Enough To Prevent Any Considerable Taper in the Bore of the Sleeve When It Cools after This Operation. To Establish Close Contact between the Sleeve and the Water-Cooled Walls of the Chuck, the Finish-Boring Operation Is Held within a Tolerance of 0.001 In.

Further use of this general method of measurement is illustrated in connection with an internal grinding-operation. (See Fig. 9.) Incidentally, and because of the very general interest which has been shown in

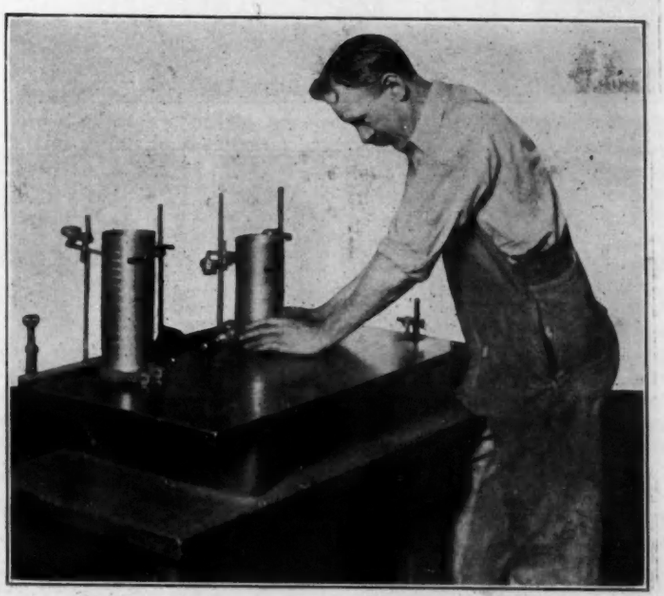


FIG. 7—MILLING THE PORTS OF A SLEEVE

Since Relatively Small Temperature-Changes Affect the Fixture, the Arbors and the Milling-Machine Itself, Care in the Control of Temperature Is Required To Maintain a Tolerance of 0.004 In. in a Length of 10 In. during the Porting Operation. One Precaution Taken Is To Run the Machine Light until Approximately Working-Temperatures Have Been Reached before the Actual Operation of Porting Is Started

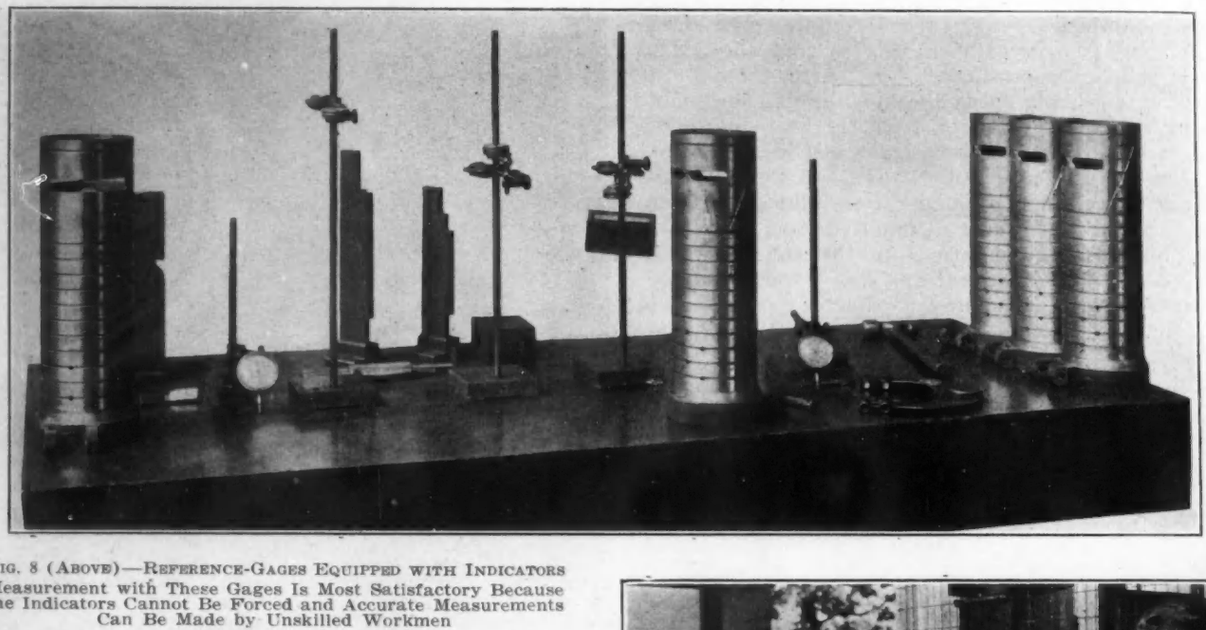
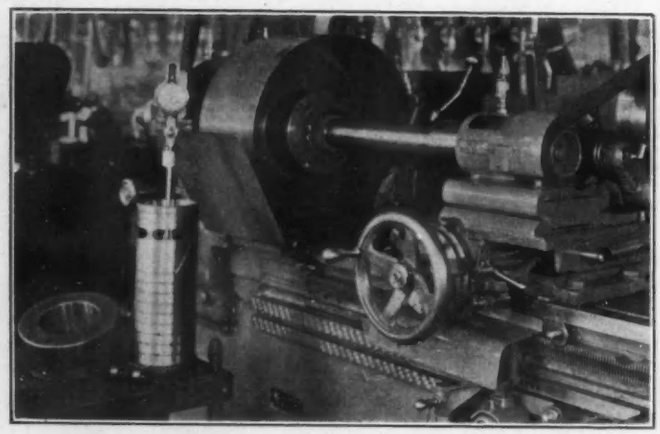


FIG. 8 (ABOVE)—REFERENCE-GAGES EQUIPPED WITH INDICATORS
Measurement with These Gages Is Most Satisfactory Because the Indicators Cannot Be Forced and Accurate Measurements Can Be Made by Unskilled Workmen

FIG. 9 (BELOW)—INTERNAL GRINDING-OPERATION
All Sleeve-Bores Are Ground and the Bore of the Inner Sleeve Is Honed after Grinding



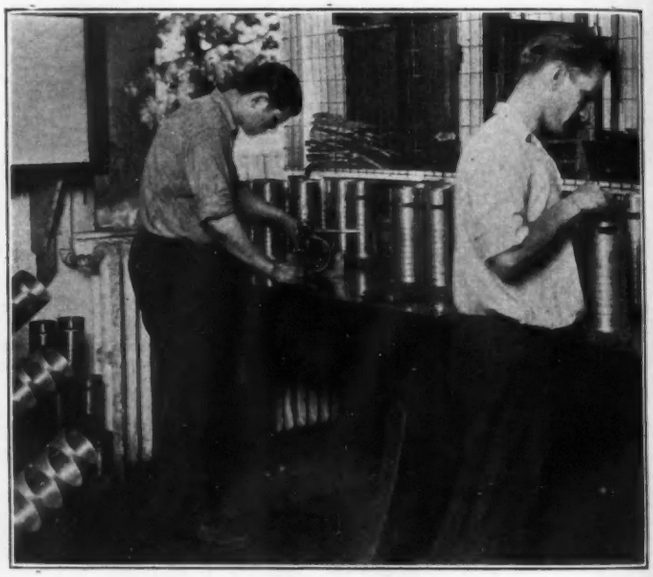


FIG. 10 (ABOVE)—FINAL INSPECTION
The Inspector at the Left Is Checking the Pinhole in Relation to the Center Line of the Sleeve-Bore. He Also Checks the Thickness of the Lugs and the Depth of Milling-Cut at the Lugs. The Inspector at the Right Is Inspecting Sleeves for Depth of the Grinding Relief. He Also Inspects the Sleeve Carefully To See That All Operations Have Been Completed, That the Quality of the Finish Is Satisfactory and That No Casting Defects Have Been Overlooked in Previous Inspection-Operations

FIG. 11 (AT LEFT)—CONTINUATION OF THE FINAL INSPECTION
The Inspector at the Left Is Checking the Diameter of the Bore. The Workman at the Right Is Checking the Outside Diameters

methods of finishing cylinder-bores, it can be stated here that it is our practice to grind all sleeve-bores. The bore of the inner sleeve, which, in a Knight engine, corresponds to the cylinder-bore in the poppet-valve engine, is honed after grinding. Honing is regarded simply as a surfacing operation, and the honing is required to remove from 0.0002 to 0.0004 in. of material only.

After the completion of machine operations and initial and intermediate inspection-operations, the finished sleeves are subjected to a close final inspection. This is partly illustrated in Fig. 10. The inspector at the left is checking the pinhole in relation to the center line of the sleeve-bore. He also checks the thickness of the lugs and the depth of the milling-cut at the lugs. The inspector at the right is inspecting sleeves for depth of the grinding relief. He also inspects the sleeve carefully to see that all operations have been completed, that the quality of the finish is satisfactory and that no casting defects have been overlooked in previous inspection-operations.

The final inspection-operations are continued as shown in Fig. 11. The inspector at the left is checking the diameter of the bore with a three-point indicator. The workman at the right is checking the outside diameters. The gage used here is a V-block with provisions for attaching indicators, and the reference gages to which the indicators are set are evident. Four adjusting-screws are provided in the V-block.

Fig. 12 shows the operation of fitting pistons into the sleeves. A shim is attached to a spring-balance scale. The shim is pulled between the piston and the sleeve-bore, and the tension or resistance of the shim is measured by and indicated on the scale. A similar method is used for determining the amount of clearance between the inner and the outer sleeve and between the outer sleeve and the cylinder-wall. This general scheme of fitting has been adopted after extended experimentation with other methods of fitting a selected sleeve.

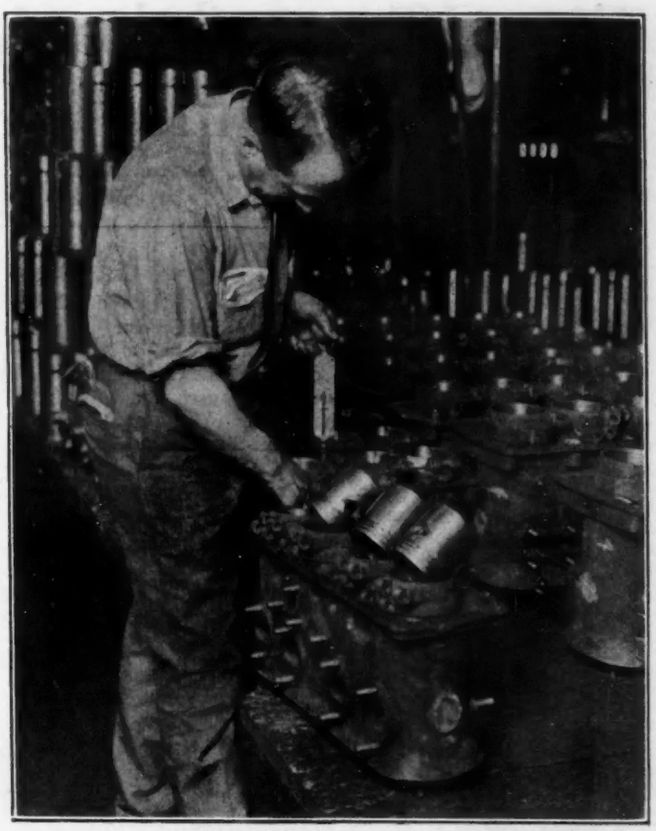


FIG. 12—FITTING PISTONS INTO THE SLEEVES
A Shim Is Attached to a Spring-Balance Scale. The Shim Is Pulled between the Piston and the Sleeve-Bore and the Tension or Resistance of the Shim Is Measured by and Indicated on the Scale. A Similar Method Is Used for Determining the Amount of Clearance between the Inner and the Outer Sleeve and between the Outer Sleeve and the Cylinder-Wall

NON-COLLEGIATE TECHNICAL INSTITUTES

PLAINLY our difficulty is not that we have too much technical education but that we have yielded to the temptation to make a fetish of the standard collegiate program and degree. The most immediate need is to provide for large numbers of young men a briefer, more practical, more intensive training than that of an engineering college, a training broader than that of a trade school and entirely distinct from that of an academic junior college. Two types of young men are to be provided for in such schools, one already employed in industry but desirous of giving a limited time to intensive technical training to facilitate his progress in chosen lines of activity and the other the secondary school graduate who does not desire an arduous theoretical preparation but seeks to enter the industrial field through its junior technical or supervisory services.

A small group of technical institutes of non-collegiate type are doing excellent work in the field described. Their graduates are able to enter active life at a fairly early age, with assured earning power, with ample time for thorough grounding in experience and with the willingness to accept the regime and environment of operating organizations. Their records indicate that they are able to rise through the ranks to positions of considerable responsibility and that a fair number of them achieve distinguished success, though more often in the line or operating fields than in the traditionally "professional" fields of engineering. The present supply of men from these sources is very small, while the demand that would certainly be created if industry undertook to adjust itself to recruitment of this kind might be expected to outrun that for college men with engineering degrees.

In every other advanced country this type of technical education is very generously provided for, and it would seem to be the complementary element most needed in our own system. Great numbers of students, who enter our colleges with a valid impulse toward technical work but without certain qualities demanded by a long and arduous theoretical training, might do themselves credit in a briefer and more practical program. With all due allowance for the college-struck attitude that prevails in our youth, probably a very much larger number of them might be directed to such a program if it were more widely provided, given suitable formal public recognition by the public and the engineering profession and its merits set forth by adequate publicity.—W. E. Wickenden in a report to the Society for the Promotion of Engineering Education.

The Effect of the Addition of Kerosene on the Oiliness of Lubricating-Oils[1]

By S. A. McKee[2]

Illustrated with Charts, Drawings and Photographs

ABSTRACT

A REPORT is made of the results of tests of the performance of oils diluted with kerosene in a journal-bearing friction-machine with regard to the so-called "oiliness" property of the lubricant, oiliness being defined as the property that causes a difference in the friction when two lubricants of the same viscosity at the temperature of the oil-film are used under identical conditions.

A detailed description is given of the method of procedure and of the precautions taken to keep the speed, load, bearing temperature, and oil-pressure constant throughout the duration of a run.

Four series of test-runs were made with the first test-bearing, the lubricant in the several runs being respectively a light mineral motor-oil, a blend of 35.75 per cent of kerosene with 64.25 per cent of cylinder stock, the light mineral motor-oil, as a check to see whether the conditions of the bearing had changed, and the light mineral motor-oil plus 2 per cent of oleic acid. The samples were chosen so that their viscosities were very nearly the same at the temperature of operation. The results are shown in the form of curves.

In tests made with a second bearing, spindle and cylinder stock known to be from the same crude were obtained, the oil used as a reference being a blend of these two and having a viscosity about the same as that of the light mineral motor-oil used in the first bearing. Oils showing the effect of the addition of kerosene were composed of the spindle and cylinder stocks blended with 10, 20 and 30 per cent respectively of kerosene, in such proportions that the viscosity of each of the three samples was the same as that of the reference oil. The tests showed that oils of wide difference in viscosity apparently have the same oiliness, whereas Kingsbury found that high-viscosity oils possessed the property of oiliness to a greater degree than oils of low viscosity.

The conclusion reached is that, when operating with kerosene blends, the fluid film apparently breaks down and unstable lubrication begins under less severe operating-conditions than when straight mineral-oil is used. This tends to show that, under the conditions of these tests, the addition of kerosene decreases the so-called "oiliness" effect of the lubricant.

ALTHOUGH it is well known that the chief effect of crankcase-oil dilution on the lubricating-oil in an automobile engine lies in the reduction of the viscosity of the oil, this investigation of the performance of oils diluted with kerosene in a journal-bearing friction-machine tends to show that dilution has also an effect on the so-called "oiliness" property of the lubricant. This feature is of interest and may be important at least during certain periods of operation.

The term "oiliness," as used in this paper, is defined as the property that causes a difference in the friction when two lubricants of the same viscosity at the temperature of the oil-film are used under identical conditions.

A relation by which the performance of oils can conveniently be compared in a journal-bearing friction-machine has been suggested by Hersey[3] and extended by Wilson and Barnard[4]. It is based upon the theory that, for any given combination of journal, bearing and lubricant, f is a function of $\mu n/p$, where

f = the coefficient of friction
μ = the absolute viscosity of the oil in the bearing
n = the speed of the journal or shaft
p = the pressure on the projected area of the bearing

By plotting f against $\mu n/p$, a curve is obtained that is characteristic of that particular combination. Thus, by using the same journal and bearing but different lubricants, curves may be plotted by which the performance of the lubricants in the bearing can be compared.

Explanation of Formula

It should be noted that the quantity $\mu n/p$ is dimensionless, and its numerical value for any specific condition of operation is independent of the system of units employed, provided that the system is consistent. As a matter of convenience, however, the quantity ZN/P, suggested by Wilson and Barnard, has been substituted in the remainder of this discussion. This quantity, ZN/P, is specifically defined by the common engineering units,

Z = the viscosity of the lubricant in the bearing in centipoises
N = the speed of the journal or shaft in r.p.m.
P = the pressure on the projected area of the bearing in lb. per sq. in.

Since, in this term, a consistent system of units is not employed, its numerical value for any specific condition of operation is not the same as that of the theoretical modulus $\mu n/p$. It is, however, dimensionless and directly proportional to $\mu n/p$, the factor of conversion being approximately 151×10^{-10}.

This conversion factor is the product of the two factors, 2π and approximately 24×10^{-10}. The factor, 24×10^{-10}, converts centipoises to pounds per square inch divided by radians per minute, this being the viscosity unit that corresponds to the unit of pressure of the pounds per square inch. The factor 2π converts the speed in revolutions per minute to radians per minute, this being the unit of speed that corresponds to the pounds per square inch divided by radians per minute unit of viscosity.

To wipe out any possible question as to the effect of viscosity or of base in this work, it seemed essential that all the samples to be tested have approximately the same viscosity and be from crudes of the same base. Since it would be difficult to procure used crankcase oils that would meet these requirements, it was decided to use oils of the same base diluted with kerosene, on the assumption that their performance in a bearing would fairly

[1] Published by permission of the Director of the Bureau of Standards.

[2] Assistant mechanical engineer, Bureau of Standards, City of Washington.

[3] See *Transactions of the American Society of Mechanical Engineers*, vol. 37, p. 167.

[4] See The Journal, July, 1922, p. 49.

closely approximate that of oils diluted in engines, but free from grit, sludge and other contaminants.

Description of Machine Used for the Tests

The journal-bearing friction-machine available was designed primarily for wear and breakdown tests of the crankpin bearings of Liberty aviation engines and was not especially convenient for use in oiliness tests. It had been modified recently, however, and previous runs had shown that it would answer the purpose.

A photograph of the complete set-up of this machine is shown in Fig. 1, while the drawings of the general arrangement and the shaft assembly are shown in Figs. 2 and 3. The machine is driven by a 5-hp. adjustable-speed direct-current motor, connected by a flexible coupling to a gear-box having a reduction of 22.43 to 1.00. The drive from the low-speed end of the gear-box is transmitted to the steel test-shaft *a* (Figs. 2 and 3) by the flanged coupling *b*, the short shaft *c*, and the Oldham coupling *d*. This driving-system provides a range of speed of the test shaft from about 10 to 130 r.p.m., while provision is made for increasing this to 3000 r.p.m. by removing the gear-box and driving direct from the motor.

The test shaft is supported by the two main-bearings *e* and *g*. These are provided with bronze bearing-sleeves, *h* and *i*, and are mounted in the pedestals *j* and *k*, which are bolted to the bed-plate *l*.

Temperature control is provided for by making the test shaft hollow for about two-thirds its length. Hot or cold water is admitted by the control-valve *m* through the pipe *o*. The water flows back along the hollow shaft through the water-thrower *q* and is caught by the water-catcher *r*, which is provided with a hose connection to the service drain.

End-thrust on the test shaft is taken care of by the flange on the water-thrower, which acts as a thrust collar and revolves between the two stationary thrust-rings *s* and *t*. The feature of this construction is the accessibility obtained, for, after removing six 5/16-in. cap-screws, disconnecting a ¼-in. pipe-union and uncoupling a 1¼-in. hose, the shaft can be withdrawn endwise from the bearings and the bearing surfaces examined.

Mounting of Test Bearing

The bearing under test is mounted on the shaft between the two main-bearings. It is a standard Liberty-engine crank-pin bearing and consists of a bronze sleeve lined with a thin layer of babbitt metal. Its nominal bore is 2 ⅜ in., and its nominal length 2 ¼ in. The sleeve is made up of two half-bearings, *u* and *v*, which are clamped and doweled into the test-bearing block *w* in such a manner that the split between them lies in a plane passing through the center line of the bore and perpendicular to the line of application of the load. The work-

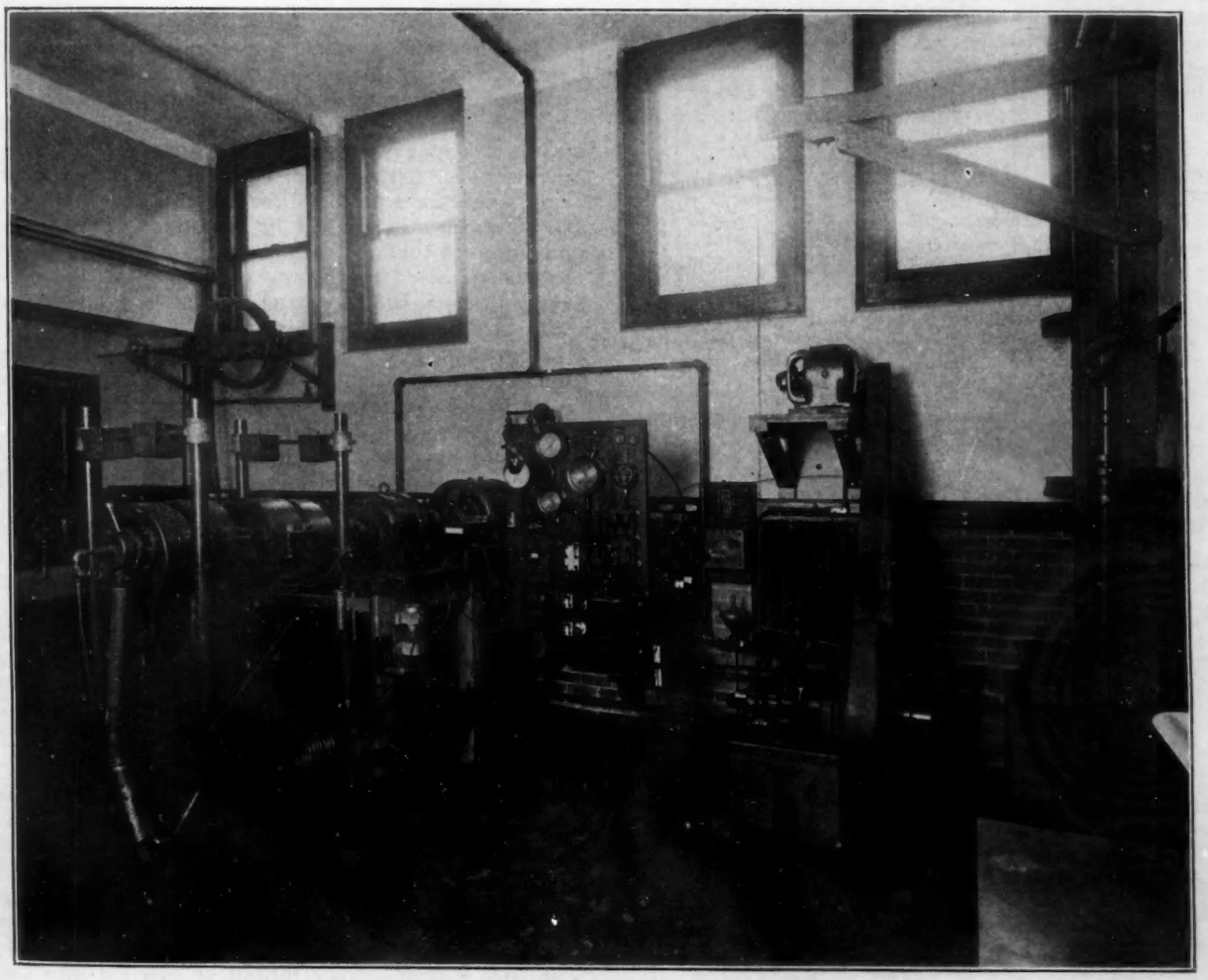


Fig. 1—Complete Set-Up of Journal-Bearing Friction-Machine Used in the Tests
The Machine Available Was Designed Primarily for Wear and Breakdown Tests of the Crankpin Bearings of Liberty Aviation Engines and Was Not Especially Convenient for Use in Oiliness Tests. It Has Been Modified Recently, However, and Previous Runs Had Shown That It Would Answer the Purpose

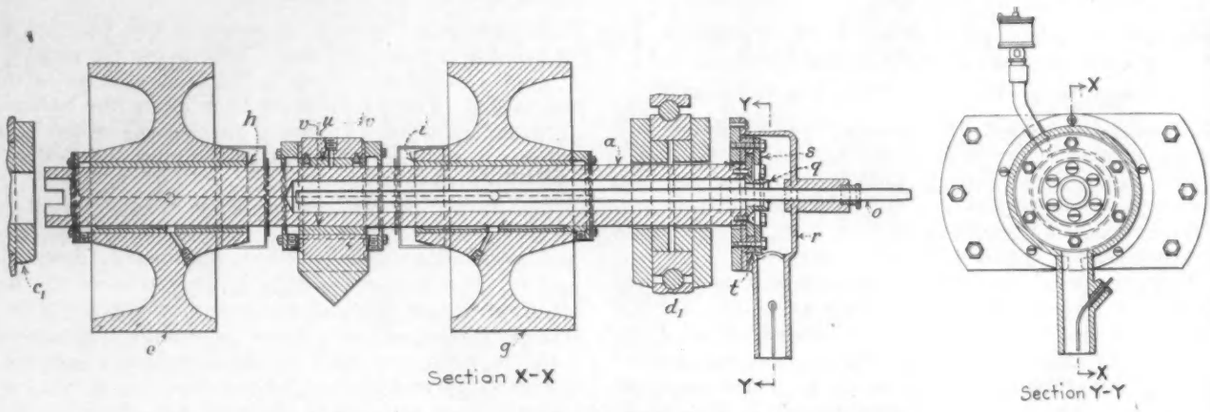


FIG. 3—SHAFT ASSEMBLY OF JOURNAL-BEARING FRICTION-MACHINE
The Drive from the Low-Speed End of the Gear-Box Is Transmitted to the Steel Test-Shaft *a* by the Flanged Coupling *b*, the Short Shaft *o*, and the Oldham Coupling *d*

ing temperature of the bearing is measured by a copper-constantan thermocouple peened in the bronze backing of the lower half-bearing along the line of the load.

The load is applied to the test bearing by the hydraulic jack *x*. Proper alignment of the load is obtained by fitting the knife-edge *y* and the V-block *z* between the bearing-block and the jack-plunger a_1. The jack is supported by the cradle b_1, which is hung from the main-bearing pedestals by the ball-bearings c_1 and d_1 and the links e_1 and g_1.

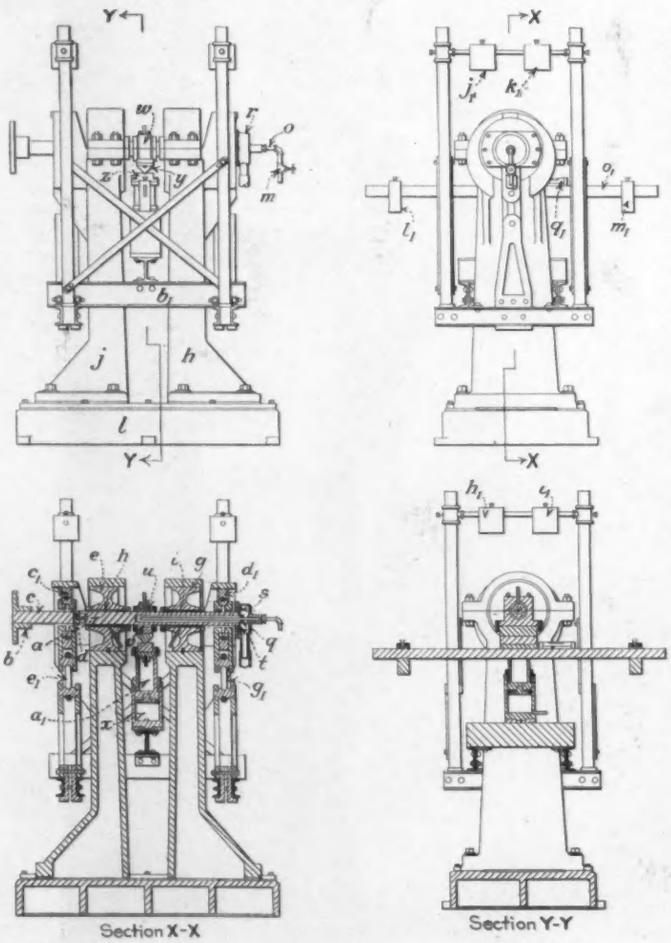


FIG. 2—GENERAL ARRANGEMENT OF JOURNAL-BEARING FRICTION-MACHINE
The Machine Is Driven by a 5-Hp. Adjustable-Speed Direct-Current Motor, Connected by a Flexible Coupling to a Gear-Box Having a Reduction of 22.43 to 1.00

Upon application of the load, the test bearing, jack and cradle act as a rigid unit that tends, when the shaft is turning, to rotate around the axis of the shaft, owing to the frictional torque set up in the test bearing. Proper balance of this system is obtained by the counterweights h_1, i_1, j_1, and k_1, and the frictional torque is measured by the counterpoises l_1 and m_1 on the graduated beam o_1. The spirit-level q_1 indicates when the system is in balance.

HYDRAULIC SYSTEM FOR APPLYING PRESSURE

The hydraulic system for applying pressure to the jack consists of an accumulator connected to a two-cylinder-opposed reciprocating motor-driven pump, *A* (Fig. 1). The accumulator is a vertical cylinder, *B*, into which is fitted a long plunger, *C*. The upper end of this plunger is fitted with a crosshead, *D*, and guides *E* and *F*; and hangers are provided for attaching cast-iron weights *G*. Pressure is applied by loading the crosshead and pumping suitable oil into the system until the plunger has been raised to the top of its stroke. The weights hanging from the crosshead act on the plunger and provide hydrostatic pressure in the system. Owing to leakage in the jack and the accumulator, the plunger of the accumulator gradually settles toward the bottom of its stroke. Variations of the friction in the packing-gland cause slight fluctuations of pressure in the system. These fluctuations are damped out by placing a throttle-valve in the line to the jack and keeping the pressure in the jack lower than that in the accumulator. To minimize the resistance to the tilting of the cradle, a flexible connection, consisting of a helical coil of copper tubing, is placed in the line to the jack. Pressure-gages are installed between the throttle-valve and the jack, to measure the load applied to the bearing. By this system, a maximum load of 30,000 lb. on the test bearing can be obtained, while lack of sensitivity of control limits the minimum value to 1000 lb., to keep with a variation of about 3 per cent.

SUPPLYING THE OIL

Oil is supplied to the test bearing, by a motor-driven gear-pump, which draws the oil from a reservoir that is provided with a stirring-tube and heating-coil, to maintain a constant temperature, and delivers it under pressure to the center of the top of the bearing. A throttle-valve, a bypass, an air-chamber, and a pressure-gage are installed to maintain a constant pressure; and a flexible coil of copper tubing is inserted into the line to the bearing to allow free tilting of the cradle. Oil-catchers and drain-pipes return the oil leaving the bearing to the reservoir.

A separate oiling-system is used for supplying the main bearings. This is similar to the one provided for the test bearing, except that temperature control is omitted.

In the use of a friction-testing machine to study the performance of a lubricant in a bearing, the greatest difficulty encountered is preparing the surfaces of the shaft and of the bearing so that they will have sufficient accuracy and smoothness to yield consistent results. This is especially true, when it is intended to operate under conditions such that a complete "fluid film" of oil is not maintained between the rubbing surfaces. Hence, extreme care was taken in this work. The shaft was "roughed out" to within a few thousandths of an inch of its proper size, was heat-treated and then ground, particular attention being paid to accuracy and finish. The two halves of the bearing were clamped together and their outer surfaces were turned to fit the bore of the

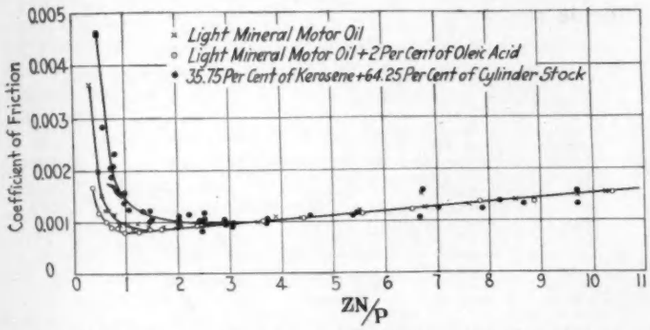

Light Mineral Motor Oil
Light Mineral Motor Oil + 2 Per Cent of Oleic Acid
35.75 Per Cent of Kerosene + 64.25 Per Cent of Cylinder Stock
Coefficient of Friction
0.005
0.004
0.003
0.002
0.001
0
0 1 2 3 4 5 6 7 8 9 10 11
ZN/P

FIG. 4—CURVE SHOWING THE VARIATION OF THE COEFFICIENT OF FRICTION WITH THE VALUE OF ZN/P

Each Point on the Curves Represents the Value of f Computed from the Average of the 30 Determinations of Frictional Torque Taken during a Single Test-Run

test bearing block. They were then assembled in the block and the bearing surface was finished with a special type of commercial reamer, consisting of three expanding-type sleeves and a cutting-knife, acting on a tapered arbor. The feature of this reamer is that the sleeves furnish ample guidance for the bearing while the knife is shaving the babbitt metal, which results in a smooth true cut. Micrometer-screw adjustment is provided for both the sleeves and the knife and allows very accurate sizing of the bore. The sleeves also provide a means for burnishing the bearing-surface.

In spite of the great care used, however, after making a few trial runs, it was found necessary to "run-in" the bearing for about 50 hr. before reproducible results were obtained. This "running-in" was accomplished by gradually increasing the load and decreasing the speed until the extreme conditions of high load and low speed expected in the actual test-runs were reached. The machine was run under these conditions until the frictional torque became practically constant.

METHOD OF MAKING A TEST-RUN

In making a test-run, the machine was brought to steady conditions under a load and speed calculated to give the desired value of ZN/P; and 10 readings of the frictional torque were taken. To eliminate the effect of friction in the ball-bearings that support the cradle, these readings were taken by locking one counterpoise and noting the positions of the other one that were required to bring the cradle to a level when it was alternately tipped in opposite directions. Since it was impossible to determine the position for zero torque, it was necessary to reverse the rotation of the shaft and to

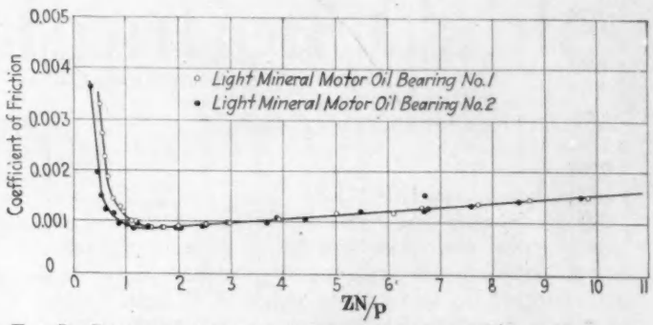


FIG. 5—COMPARISON OF THE f VERSUS ZN/P CURVES OF TWO BEARINGS OPERATING WITH THE SAME LUBRICANT

The Surface of the First Bearing Had Become Scored Owing to the Accidental Presence of Foreign Matter in the Oil and Was Replaced by the Second, Which Was Made To Reproduce as Nearly as Possible the Conditions of Clearance and Smoothness of Surface Present in the First One

take 10 more readings, the difference between the averages of the two sets of readings being twice the average frictional torque during the run. A check was then made by taking 10 more observations with the shaft turning in the original direction. Care was taken to keep the speed, load, bearing temperature and oil-pressure constant throughout the duration of a run. Precautions were necessary, in reversing the direction of rotation, to prevent the scoring of the shaft or the bearing. The load on the bearing was decreased to a value just large enough to prevent the shifting of the knife-edge on the V-block, and the driving-motor was "plugged-in" in the reverse direction before the shaft stopped.

Four series of test-runs were made with the first test-bearing. The lubricant used in the first, as a basis of comparison, was a light mineral motor-oil; in the second a blend of 35.75 per cent of kerosene with 64.25 per cent of cylinder stock; in the third, the light mineral motor-oil, as a check to see whether the conditions of the bearing had changed; and, in the fourth, the light mineral motor-oil plus 2 per cent of oleic acid. These samples were chosen so that their viscosities were very nearly the same at the temperature of operation.

RESULTS OF THE TESTS

The results of these tests are shown by the f versus ZN/P curves in Fig 4. Each point on the curves represents the value of f computed from the average of the 30 determinations of frictional torque taken during one test-run. It will be noted that, at the right of the

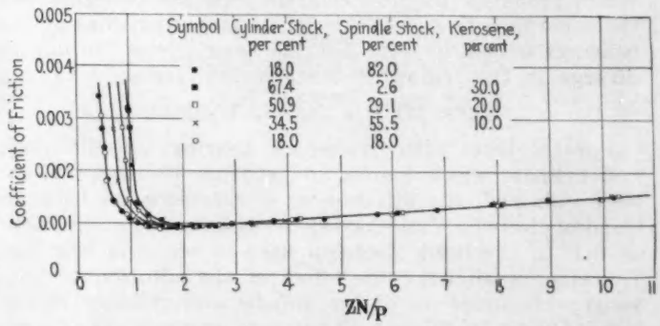


FIG. 6—CURVES SHOWING THE VARIATION OF THE COEFFICIENT OF FRICTION FOR DIFFERENT VALUES OF ZN/P IN DIFFERENT BLENDS OF SPINDLE STOCK, CYLINDER STOCK AND KEROSENE

The Reference Oil Was a Blend of the Spindle Stock and the Cylinder Stock, Having a Viscosity About the Same as That of the Light Motor-Oil Used in the First Bearing. Oils Used for Showing the Effect of the Addition of Kerosene Were Composed of the Spindle and Cylinder Stocks Blended with 10, 20 and 30 Per Cent Respectively of Kerosene, in Such Proportions That the Viscosity of Each of the Three Samples Was the Same as That of the Reference Oil

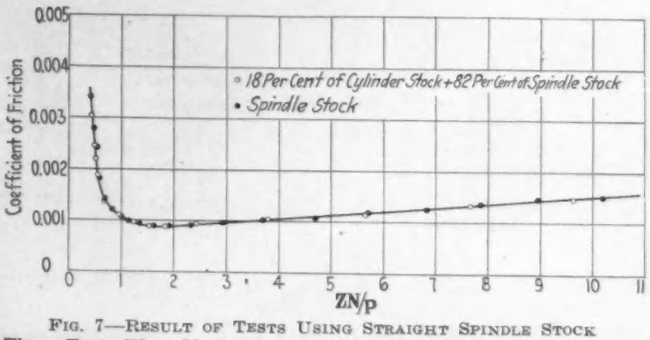


FIG. 7—RESULT OF TESTS USING STRAIGHT SPINDLE STOCK
These Tests Were Made To Make Sure That the Difference in Performance Shown by the Curves in Fig. 6 Was Due Entirely to the Kerosene and Not to the Difference in the Percentages of the Spindle and Cylinder Stock in the Various Samples

figure, the curves for the various oils coincide and form a straight line, with f decreasing as ZN/P decreases. This is the region of so-called "stable lubrication", in which a complete fluid-film of lubricant supposedly separates the journal from the bearing, and f is dependent only upon ZN/P. Toward the left of Fig. 4, the curves break away from the straight line, a point of minimum coefficient of friction being attained in each case. This is the region in which the fluid film breaks down. To the left of this region lies the region of so-called "unstable lubrication", where f rises rapidly as ZN/P decreases and is no longer a function of ZN/P alone.

The results of the first and the third series of tests, in which the same lubricant was used, were so nearly identical that they are shown by a single curve. This would tend to indicate that very little change in bearing conditions took place during a test.

During the fourth series of tests, an effort was made to obtain a point with a lower value of ZN/P than is shown on the curve but, owing to the accidental presence of foreign matter in the oil, the surface of the bearing became scored. This necessitated a discontinuance of the test and the installation of a new bearing.

In the preparation of this second bearing for test, an effort was made to reproduce the conditions of clearance and smoothness of surface present in the first one. The bearing was sized and finished with extreme care and the running-in process was duplicated as closely as possible. Fig. 5, which shows the f versus ZN/P curves of the two bearings operating with the same lubricant, indicates the degree of reproduction attained. In the region of stable lubrication, the curves practically coincide, which probably indicates that the effective clearance was the same in both cases, but the surface conditions of the bearings evidently were not the same, since the curves diverge in the region of unstable lubrication.

TESTS WITH A SECOND BEARING

For the tests with the second bearing, spindle stock and cylinder stock known to be from the same crude were obtained, the oil used as a reference oil being a blend of these two, and having a viscosity about the same as that of the light motor-oil used in the first bearing. The oils for showing the effect of the addition of kerosene were made up of the spindle and cylinder stocks blended with 10, 20 and 30 per cent respectively of kerosene, in such proportions that the viscosity of each of the three samples was the same as that of the reference oil.

The results of the tests of these oils are shown by the curves in Fig. 6. Tests of the reference oil were made both before and after the kerosene blends had been tested, to compare the bearing conditions before with those after the runs. No measurable difference was found.

To make sure that the difference in performance shown by the curves in Fig. 6 was due entirely to the kerosene and not to the difference in the percentages of the spindle or cylinder stock in the various samples, a series of tests was made using straight spindle-stock. A comparison of the results of this series with those of the series using the reference oil is shown in Fig. 7. Since the curves are practically identical, it appears certain that the differences brought out by the curves in Fig. 6 are due entirely to the kerosene.

It is interesting to note that, in this test, oils of wide difference in viscosity apparently have the same oiliness whereas Kingsbury[5] found that high-viscosity oils possessed the property of oiliness to a greater degree than oils of low viscosity.

Table 1 gives data relating to the running conditions during the tests.

TABLE 1—RUNNING CONDITIONS DURING THE TESTS

Diameter of Test Shaft, in.	2.3750
Diameter of Test Bearing No. 1, in.	2.3778
Diameter of Test Bearing No. 2, in.	2.3778
Length of Test Bearings, in.	2.25
Maximum Total Load on Test Bearing, lb.	15,200
Minimum Total Load on Test Bearing, lb.	1,430
Maximum Pressure on Test Bearing, lb. per sq. in.	2,840
Minimum Pressure on Test Bearing, lb. per sq. in.	268
Maximum Speed of Shaft, r.p.m.	45
Minimum Speed of Shaft, r.p.m.	11
Average Viscosity of Spindle Stock at Running Temperature, centipoises	50[a]
Average Viscosity of All Other Oils Tested at Running Temperature, centipoises	100[a]
Average Running Temperature, deg. cent.	25[a]
Average Running Temperature, deg. fahr.	77[a]

[a] Approximate.

CONCLUSIONS

The curves in Fig. 4 and Fig. 6 indicate that the effect of the addition of kerosene to the lubricating-oil is to increase the value of ZN/P where the point of the minimum coefficient of friction is reached; in other words, when operating with kerosene blends, the fluid film apparently breaks down and unstable lubrication begins under less severe operating-conditions than when straight mineral-oil is used. This tends to show that, under the condition of these tests, the addition of kerosene decreases the so-called "oiliness" effect.

If used crankcase-oils suffer a like decrease in oiliness, possibly the greatest effect in the operation of the engine would be noted in the lubrication of the piston-rings. It is reasonable to expect that, at least during some periods of operation, the rings are operating in the region of so-called "unstable lubrication", where a decrease in the oiliness of the lubricant may have an appreciable effect on frictional loss and wear. Referring to Fig. 4, it will be interesting to note that the decrease in oiliness due to the addition of kerosene is comparable with the increase in oiliness due to the addition of fatty acid.

The effect on the lubrication of bearings is possibly of less moment. Under normal conditions, they probably are operating for the most part in the region of stable or complete-film lubrication, where no wear should occur and where viscosity is the only property of the lubricant that affects friction loss. Inasmuch as bearings do wear in actual service, however, there probably are times, notably while starting or stopping the engine, during which they are operating in the region of unstable lubrication, where the oil-film is not complete. It is during these periods that a decrease in oiliness could be expected to show some effect on frictional loss and wear.

[5] See *Transactions of the American Society of Mechanical Engineers*, vol. 24, p. 143.

Corona Tests of Ignition Cables

By F. L. HAUSHALTER[1] *Illustrated with* CHARTS AND DIAGRAMS

ABSTRACT

A METHOD of testing ignition cables by the corona test is described and the results of a series of tests are given. According to the Townsend theory of the ionization of a gas by collision, corona is said to be the result of the bombardment of gas ions, which multiply and remultiply with increasing velocity as the potential gradient is increased, and to be started by the energy of the rapidly moving ions necessary to produce ionic saturation. Further increase in the electric field beyond the point of ionic saturation causes a sudden increase in the current. The corona stage is reached when the air becomes conductive. The cracking that is observed when an ignition cable is subjected to corona is due to ozone generated by the corona, which is usually detected by a purple glow and a hissing noise.

Soft vulcanized rubber when unstressed is not affected by ozone but when stretched even a small amount in the same atmosphere of ozone cracks severely in less than 1 min. Protective coatings, such as cellulose films or fabricated coverings, mitigate and often eliminate this cracking. Tests show that the degree of the cracking of soft vulcanized rubber when stretched and subjected to ozone decreases as the tension is increased beyond a definite point.

In order to get consistent results in corona tests of ignition cables the cables of various thicknesses should always be stretched equal amounts per unit of original length, and the corona discharge should be controlled accurately to obtain a definite ozone concentration on the surface of the cable. Apparatus for obtaining such results is described and illustrated.

IN order to formulate a suitable specification for a corona test of ignition cables, it is necessary to understand some of the fundamentals governing such a test. The cracking that is observed when an ignition cable is subjected to corona is due to ozone generated by the corona. Air is a mechanical mixture of nitrogen, N_2, and oxygen, O_2. The electrical stress, when above a definite critical potential gradient, breaks up the oxygen, O_2, into O, which combines to form ozone, O_3. Ozone and ionized oxygen are much more active chemically than ordinary oxygen. The oxygen is perhaps broken up, at potential gradients above a definite critical value, in accordance with Townsend's theory of ionization of a gas by collision. According to this theory, corona is the result of a bombardment of gas ions, which multiply and remultiply with increasing velocity as the potential gradient is increased. It may be said that corona is started by the energy of the rapidly moving ions necessary to produce ionic saturation. A further increase in the electric field beyond the point of ionic saturation causes a sudden increase in the current. This is the corona stage; the air becomes conductive. Corona is usually detected by a purple glow and a hissing noise.

STRETCHING OF RUBBER CAUSES CRACKING

Soft vulcanized rubber, when not stressed in any way, has been continuously subjected to ozone for hours without deleterious effects; but when stretched even a small amount, in the same atmosphere of ozone, it cracked very severely in less than 1 min. Soft vulcanized rubber, then, is cracked by ozone in very short periods of time, a matter of seconds or of minutes, only when placed in tension. It has been found that the cracking occurs on the side that is under tension, never on the side that is under compression. Crude rubber, smooth sheets of Hevea Braziliensis unvulcanized, as received from the importer, cracks more severely than soft vulcanized rubber, when stretched and subjected to ozone for short periods of time.

Protective coatings on the rubber, such as cellulose films or fabricated coverings, mitigate and often eliminate the cracking of stretched rubber in the presence of ozone. These coatings apparently protect the rubber from the ozone. A fabric of fine mesh is more effective than a fabric of coarse mesh. Cellulose films eliminate the cracking entirely, unless the film has been broken in bending.

DEGREE OF CRACKING DECREASES AS TENSION IS INCREASED

The degree of cracking of soft vulcanized rubber, when stretched and subjected to ozone, decreases as the tension is increased beyond a definite point. In Fig. 1 are shown the results of tests on a sheet of soft vulcanized rubber, when placed successively under increasing amounts of tension and each time subjected to 12,000 volts for 2 min. Tests Nos. 1 and 2, which show the

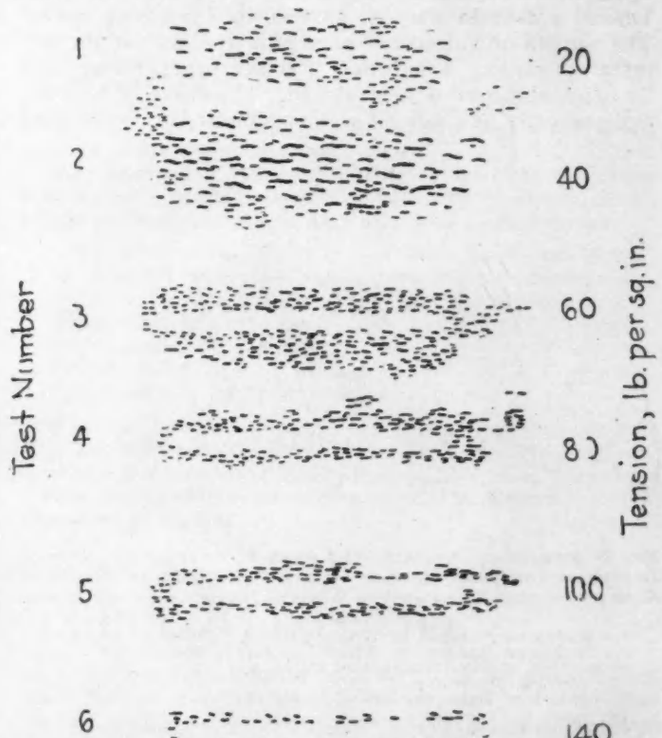


FIG. 1—EFFECTS OF CORONA ON RUBBER

The Degree of Cracking of Soft Vulcanized Rubber, When Stretched and Subjected to Ozone, Decreases as the Tension Is Increased beyond a Definite Point. The Illustration Shows the Result of Testing a Rod ⅜ In. in Diameter for 2 Min. at 12,000 Volts under Varying Tensions

[1] B. F. Goodrich Co., Akron, Ohio.

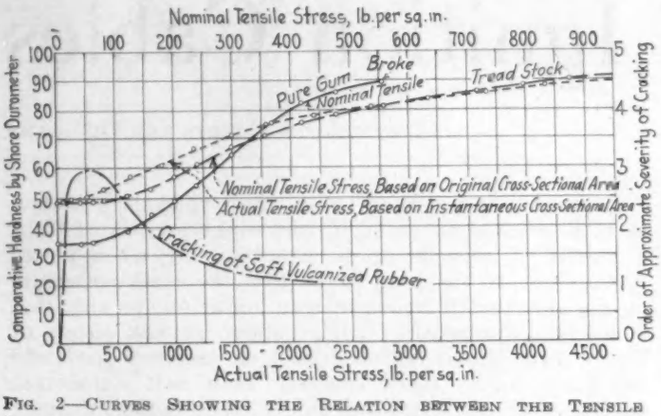

Nominal Tensile Stress, lb. per sq. in.
0 100 200 300 400 500 600 700 800 900
Pure Gum
Broke
Nominal Tensile
Tread Stock
Nominal Tensile Stress, Based on Original Cross-Sectional Area
Actual Tensile Stress, Based on Instantaneous Cross-Sectional Area
Cracking of Soft Vulcanized Rubber
Comparative Hardness by Shore Durometer
Order of Approximate Severity of Cracking
0 500 1000 1500 2000 2500 3000 3500 4000 4500
Actual Tensile Stress, lb. per sq. in.

FIG. 2—CURVES SHOWING THE RELATION BETWEEN THE TENSILE STRESS AND THE HARDNESS OF SAMPLES OF SOFT VULCANIZED RUBBER AS MEASURED WITH A SHORE DUROMETER

The Rubber Was in the Form of a Soft Vulcanized Sheet, the Cross-Section Being 1 In. Wide and ¼ In. Thick. The Room Temperature Was 85 Deg. Fahr.

most severe cracking, were performed at the lowest values of tension. The tension for Test No. 2 was 40 lb. per sq. in. (2.81 kg. per sq. cm.); the cracks were much deeper and longer than in Test No. 4 in which the tension was 80 lb. per sq. in. (5.62 kg. per sq. cm.). This may be accounted for by the fact that the rubber, under the higher tensions, is harder and therefore more resistive to the oxidizing attack of the ozone. The curve sheet, Fig. 2, shows the relation between the tensile stress set up in samples of soft vulcanized rubber, 1/4 in. (6.37 mm.) thick, and their hardness as measured with a Shore durometer, a blunt needle-point pressure-gage instrument, especially adapted to rubber. The samples did not assume increased hardness at slight elongations, but the hardness increased rapidly when stretched beyond a definite amount, as seen by the rising curves. The sample of vulcanized pure gum reached, at its ultimate elongation, a hardness 150 per cent greater than its original hardness unstretched. The curve of approximate severity of cracking of a pneumatic-tire tread-stock is plotted to show that the maximum degree of cracking is obtained just where the stock begins to increase in hardness; the cracking then decreases very rapidly as the hardness curve rises.

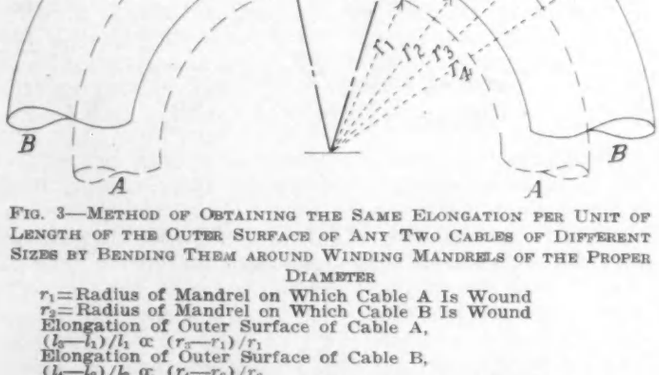


FIG. 3—METHOD OF OBTAINING THE SAME ELONGATION PER UNIT OF LENGTH OF THE OUTER SURFACE OF ANY TWO CABLES OF DIFFERENT SIZES BY BENDING THEM AROUND WINDING MANDRELS OF THE PROPER DIAMETER

r_1 = Radius of Mandrel on Which Cable A Is Wound
r_3 = Radius of Mandrel on Which Cable B Is Wound
Elongation of Outer Surface of Cable A,
$(l_3 - l_1)/l_1 \propto (r_3 - r_1)/r_1$
Elongation of Outer Surface of Cable B,
$(l_4 - l_2)/l_2 \propto (r_4 - r_2)/r_2$
For Equal Elongations Per Unit of Length of Each Cable,
$(r_3 - r_1)/r_1 = (r_4 - r_2)/r_2$
If $r_1 = 0.50$ In. and Cable A Is 0.25 In. Thick, then, Since $r_3 = 0.75$ In.,
$(0.75 - 0.50)/0.50 = (r_4/r_2) - 1$,
or
$r_4/r_2 = 1.50$
Since $r_4 = r_2 +$ Thickness of Cable B, r_2 Can Be Found In Any Case To Give the Same Percentage of Elongation of the Two Cables

PREPARING CABLES FOR TEST

The apparatus for making the corona tests on ignition cables should be so designed that the outer surface of cables of various thicknesses shall always be stretched equal amounts per unit of original length. Relations are shown in Fig. 3 by which the same elongation per unit of length of the outer surface of any two cables of different sizes may be obtained, when the cables are bent around winding mandrels of the proper diameter.

Having given the outer surface of the cable a definite elongation per unit of length, an elongation of 50 per cent is recommended, the corona discharge should be applied where the rubber is under tension and not where it is under compression. It is necessary to control the corona discharge by very accurate methods in order to obtain a definite ozone concentration at the surface of the cable.

DESCRIPTION OF TESTING APPARATUS

An arrangement is shown, in Fig. 4, by which the author has obtained very consistent results on cables of various makes. For 1/4-in. cable, a winding-mandrel 1 in. in diameter was used; this gives a 50-per cent elongation of the outer surface of the cable. The cable was wound on the mandrel and the ends were made fast. A metal strip, 1/8 in. thick, having one edge rounded to 1/16-in. radius, rested on the cable as shown. A potential of 6600 volts, alternating current, at 60 cycles, was obtained by connecting three instrument potential-transformers in series. Such transformers are made very accurately. A voltmeter and an ammeter can be inserted in the low-voltage circuit to indicate any variations. A resistance can be used to control the voltage. The voltage wave should be as near sinusoidal as possible and the frequency constant. Temperature and pressure should vary only within small limits and the cable under test should be guarded from air-currents, for such currents, obviously will produce variations in the ozone concentration at the surface of the cable under test.

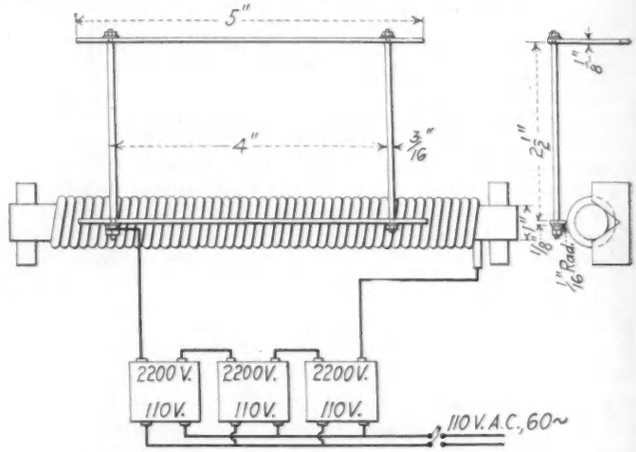


FIG. 4—APPARATUS WITH WHICH THE AUTHOR HAS OBTAINED VERY CONSISTENT RESULTS ON CABLES OF VARIOUS MAKES

For ¼-In. Cable, a Winding-Mandrel 1 In. in Diameter Was Used; This Gives a 50-Per Cent Elongation of the Outer Surface of the Cable. A Potential of 6600 Volts, Alternating Current, at 60 Cycles, Was Obtained by Connecting Three Transformers in Series

By the apparatus of Fig. 4, using General Electric instrument potential-transformers, the current in the low-voltage circuit was 0.70 amp. This was really the magnetizing current taken by the transformers. For cables of various kinds and thicknesses, this value changed but slightly. The condenser formed by resting the top electrode on the cable and connecting the other electrode to the copper of the cable is of such minute capacity that the current value, and therefore the voltage, remains practically constant for specified lengths of various kinds of cables. When the experiment was performed in a darkened room, the corona was visible to the eye. There was also a slight hissing sound and the characteristic odor of ozone.

Causes of Difference in Degree of Cracking

A rubber-covered ignition-cable used by one prominent automobile company withstood this test for 1 hr. without any sign of cracking; another sample of rubber-covered ignition-cable was cracked very noticeably in 3 min. An ignition cable that will withstand this test better than any other is perhaps a cable made of vulcanized rubber that has a high permanent-set. When such a cable is bent, the tension on the surface of the cable is very materially relieved. The actual bending-tension, for a specified radius of curvature, will therefore be a great deal less than that obtained for a "live" rubber, one that has a low permanent-set. This accounts, to a great extend, for the difference in the degrees of cracking of various cables.

It is possible to have a cable that will withstand a severe corona-test and have a short life so far as service and aging are concerned. It is necessary, therefore, to incorporate other requirements or tests, in addition to a corona test, in order to be sure of obtaining an entirely satisfactory ignition-cable.

CANADIAN FARMERS' WHEAT POOL

THE farmers of Canada have established the largest cooperative wheat organization of its kind in the world. The Canadian wheat pool, with its three units in Manitoba, Saskatchewan and Alberta, according to the Canadian Government Information Bureau, now has a membership of 120,000 farmers who control 13,230,000 of the 21,000,000 acres sown to wheat last year in the three prairie Provinces, and this pool is handling the sale of the greater part of the wheat production of Canada.

The first of the pools started in Alberta in October, 1923, and at the close of the pool year, on July 15, 1924, had handled 34,500,000 bu. of wheat. The price realized by the pool was $1.01⅝ per bu. Comparisons show that the pool was instrumental in obtaining for its members at least $2,000,000 more than would have been the case had the pool not been in operation. This success of the Alberta pool encouraged similar organizations that were being assembled separately in Manitoba and in Saskatchewan, and in the fall of 1924 the three were merged in one great marketing organization known as the Canadian Corporation Wheat Producers, Ltd., incorporated under Federal charter and with wide powers.

Each of the provincial pools is responsible for gathering the wheat of its members and placing it at the disposal of the central selling agency. Each Province is divided into 7 main districts, and each of these districts into 10 subdistricts, making 70 subdistricts all told. The individual farmer members vote once a year for a representative at the annual meeting, and 70 delegates so elected are called together in convention to discuss and develop policies. The delegates also meet in 7 groups of 10 each and elect a director, and the 7 directors so elected constitute the Provincial Board, so that the responsibilities for the government of the pool are in the hands of the members themselves, a strong point of the whole organization. Thus a body that is thoroughly democratic, organized like a miniature government but conducted on a business basis and with each individual farmer member having much more control than any general shareholder in a stock company in this Country is established. The members join under long-term contracts averaging 5 years. The membership fee is only $3, $1 of which is for a capital share and $2 for organization expenses.

Cuts Down Distributing Costs

This organization owns or has under control hundreds of elevators on the fighting-line. The wheat is handled at cost, and therefore at a saving to the farmer, and by reason of its direct connections many of the handling charges between producer and consumer are eliminated. The farmer is relieved of the necessity of guessing the right time to sell his grain, a problem that is now placed in expert hands, and he is assured of the average price for the year on all wheat he sells. This orderly marketing avoids the disastrous effects of the flooding of the market in the fall which prevails under the old system.

The Government report says that to estimate in dollars and cents the actual increase in the price of wheat attributable to the operations of the wheat pool is difficult, but

> The pool, controlling as it does more than 50 per cent of Canada's exportable surplus, has the opportunity of preventing large quantities of wheat being rushed on the market and creating a glut that inevitably forces prices down. The strength of the pool lies in its stabilizing power and in its facilities for selling in great quantities and in all countries.

If a big business organization of farmers, like that in Canada, were effected here, it would be directly and unequivocally a control of food products, that most distasteful of operations in the conception of the Department of Justice.—*Bache Review.*

PERSONAL ADJUSTMENTS IN COLLEGE LIFE

THE personal adjustments associated with American college life are more swift and more critical than those demanded of any other social group. Beginning with a sudden release from home restraints and parental guidance, they run the whole gamut from a new method of eating meals to a complete recasting of moral values and religious beliefs. They invest the American college with a quality that is scarcely known elsewhere in the world. To the student experiencing this personal revolution, the college is only incidentally a seat of learning, it is the great experiment station of youth for self-discovery and self-expression. In our wholly mobile society some such intermediate stage between the home with its limited backgrounds and horizons and the all-important choice of life interest is part of the necessary machinery of democracy. All factors considered, the wonder is not that so many fail, but that so many succeed.—W. E. Wickenden in a report to the Society for the Promotion of Engineering Education.

Inspection Along the Line

By A. H. FRAUENTHAL[1]

PRODUCTION MEETING PAPER *Illustrated with* CHARTS, DRAWINGS AND PHOTOGRAPHS

ABSTRACT

ALTHOUGH production has been increased greatly during the last decade by the use of special automatic machinery, conveyors and improved methods, plans for the application of wage incentives to indirect labor have not been widely adopted. Inasmuch as time-studies and some sort of wage-incentive system have served to keep the individual output of direct labor close to its assignment, the assumption is made that the labor of the indirect workers might also be so measured to a standard that the compensation would be governed by the quantity and the quality of the ultimate output.

The advantages and functions of inspection are discussed and a method is suggested for establishing a quality-bonus incentive-plan based on the amount of rejected and scrap material per car and the number of inspectors employed per unit of production. The manner of determining the number of inspectors in use at many plants is explained and the conclusion is reached that this number should be decided after a very thorough study of each department on the basis of scientific job-analysis.

Cam-rollers are cited as an illustration and a detailed description is given of the various inspection operations required in producing this unit. Reasons for the superiority of the direct-reading to the plug-gage method of inspection are given and comparative time-studies are reproduced in chart form.

Justification for time-studies is said to be found in the facts that (*a*) each inspector knows that a certain amount of work is expected of him; (*b*) the foreman can check the inspector's output rapidly and economically; (*c*) the chief inspector can check the output of a department over any given period with very little trouble; (*d*) the attention of everyone concerned is drawn to the possibility of economizing by better methods, mainly by impressing upon him the extreme slowness of some operations; and (*e*) a time-study is of assistance in planning the work, for the length of time necessary to keep an inspector on a job is known beforehand.

Flexibility is said to be an essential of an inspection system, and the most economical method, particularly with regard to material purchased outside, to be based partly on the importance of the various dimensions and partly on the general accuracy of each dimension as produced by the vendor.

In production-line inspection, a method of allotting a fairly definite time-interval for a given inspection is to adapt the inspection to a station in the line with a definite inspection-specification balanced in time with the production operations. This method applies particularly to Brinell testing large castings, such as cylinder-blocks and crankcases in the rough. When an inspection station is placed at the end of a line, the effect is to eliminate some of the machine inspection as well as to speed-up the final inspection.

DURING the last decade enormous strides have been made in increasing the production per man-hour by the use of special automatic machinery, conveyors and improved methods. Not only has the individual output been increased but, through time-studies, a fairly definite amount of work can be assigned to each workman for a given period. The use of some sort of wage-incentive system keeps the individual output reasonably close to its assignment. Considerable discussion has taken place among factory executives in industry as to the possibility of applying wage incentives to indirect labor but, although various methods and plans have been suggested, such a plan has not been widely adopted.

Practically all material is purchased on some sort of specification. It is fabricated and assembled into the finished product according to certain standards and specifications. Productive labor likewise is measured according to the standard of output per man-hour. Considering all this, it seems reasonable and desirable to assume that the labor of indirect workers, which plays a large part in the manufacture of any given product, might be so measured to standard that the compensation would be governed by the quantity and the quality of the ultimate output.

BENEFITS OF INSPECTION SERVICE

One of the greatest benefits of inspection service comes from its power to bring promptly to the attention of the department foremen and the production-control departments information as to the difficulties encountered with material and equipment. The inspector, being a keen observer, has one of the first opportunities to notice irregularities. This function of the inspector is as valuable to the management as is the inspecting of the finished product. In the assembling divisions, keenness and alertness are as important as in the machining divisions. There is always a tendency for work to slip away from the established standards of quality, usually by such small daily increments that the changes are hard to detect. Cutting and assembling tools, measuring devices, gages, and precision instruments are subject to wear. The fact that the wear does not take place rapidly or evenly makes it necessary for the inspector to be even more vigilant in the inspection. The ultimate effect is that, in spite of every reasonable precaution, quality will sometimes slip and errors will be made that will not be detected until the parts are issued for assembling.

[1]Jun. S.A.E.—Chief inspector, Chandler Motor Car Co., Cleveland.

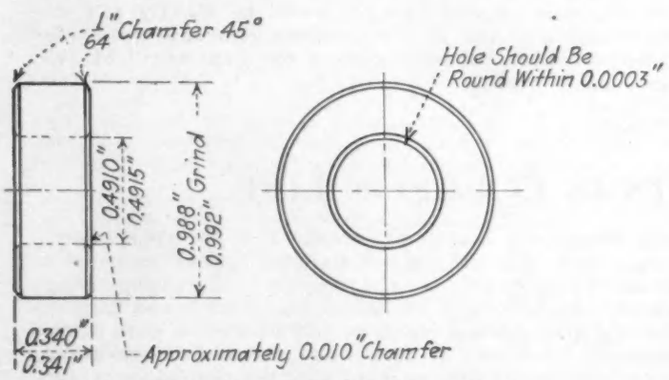


FIG. 1—SKETCH OF VALVE-LIFTER ROLLER
The Standard Time for the Inspection of a Complete Roller Is 0.25 Min. and the Hourly Production, 240

Frequently, the effect is manifested first by increased difficulty in assembling, which is fortunate, as it draws immediate attention to the basic trouble. On the other hand, errors may make the parts easier to assemble, which is dangerous. This seems to indicate that the entire inspection department could profitably be placed on a quality-bonus basis.

From the salvage-department reports of past perform-

OPERATION AND ROUTING SHEET

Date 2-16-26 Division Chandler Group No.

Part Name Valve Lifter Roller Part No. 12394

Material SAE #1020 Model 35 Req. per car 12 Sheet No. 1

OPER. No.	OPERATION	PRICE	HRLY. PROD.	TOOL No.	TOOLS OR EQUIPMENT
1	a. Remove rollers from shipping box. b. Wash in gasoline c. Transfer to inspection bench		8438		Sieve Can Gasoline
2	a. Mount rollers on steel rod b. Wipe off c. Inspect		2259		Inspection Bench Steel Rod Rags
3	a. Swab out inside diameter b. Inspect I.D. for size, .491" – .4915" and out of roundness .0004". c. Sort		790		Inspection Bench Direct Reading Indicator Holding Fixture for Rollers
4	a. Test for scelerescope hardness 4 spots on O.D. 75–85.		592		Inspection Bench Scelerescope Instrument Foot Pedal Attachment Special Holding Fixture for Roller
5	a. Mount roller on mandrel b. Place mandrel on centers c. Inspect for eccentricity & lateral runout .002" Note:– This operation performed only on approx. 10% of rollers		221		Inspection Bench (1) Pair Bench Centers (1) Mandrel (1) Ames Gage (2) "Last Word" Indicators
6	a. Wipe off roller b. Inspect for thickness .340" – .341" Note.– This operation performed only on approx. 10% of rollers		514		Inspection Bench Davie Indicator
	Standard Time Per Complete Roller Hourly Production		.250 240	Minutes	

Supersedes Sheet Dated

Remarks

Approved

FIG. 2—OPERATION AND ROUTING-SHEET
The Sequence of the Various Inspection Operations, the Production of Each One and the Tools and Equipment Required Are Listed in Order

ance, the amount of rejected and scrap material could be priced and divided by the number of cars or units produced during a given period. This would establish, in an approximate degree and on a car or unit basis, the average amount of rejected material. The number of inspectors required could be ascertained from employment-record analysis, job analysis and car or unit production. These factors having been determined, it would then be possible to establish a quality-bonus incentive-plan for the inspection department.

Stop Watch Method Used Mainly on Bench Operations

All inspection operations in the entire plant cannot be timed and standardized; therefore, only work of a repetitive nature, or bench operations, would come under the classification of the stop-watch method in determining a standard for the rate to be set. It is not assumed that all the inspection stations can be standardized to an exact degree, but the best devisable methods should be used to arrive at a standard that will reveal the approximate number of inspectors required, according to the number

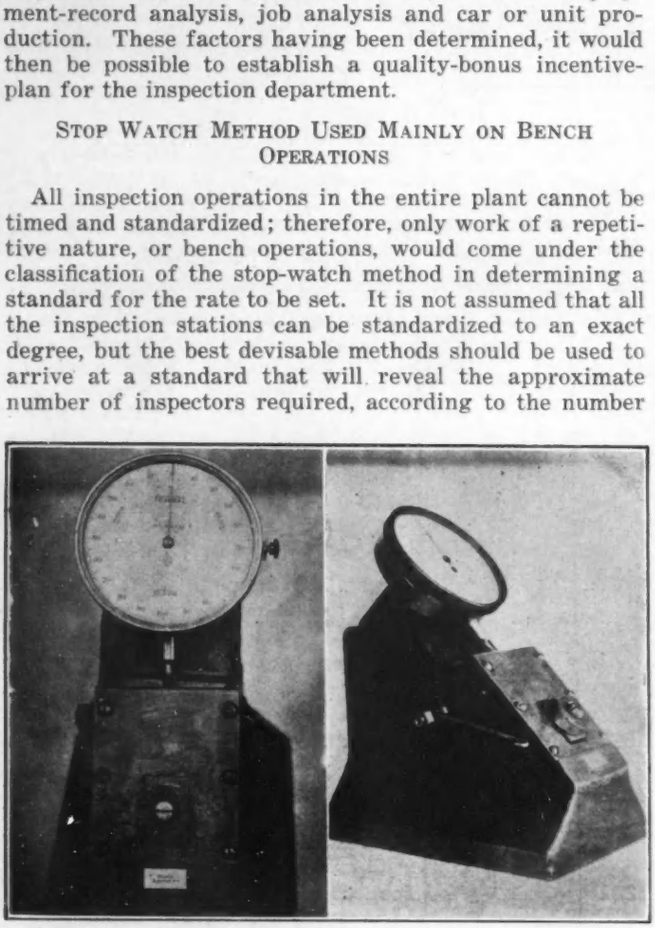


Fig. 3—Special Direct-Reading Dial-Gage
The Rollers Are Here Classified for Diameter of Bore and Are Checked for Roundness as Well as for Being within the Specified Limits of Size. The Gage Consists of One Stationary and One Movable Measuring-Point, Both of Which Are Approximately Half-Circles Having a Diameter Slightly Smaller Than the Diameter To Be Checked

of direct workers engaged and the output of these workers. It is reasonable to assume that, if careful consideration is given to the establishing of inspection standards, much higher quality will be obtained, and a decided saving in, and a much larger quantity of, material will be inspected per man-hour.

The quality-bonus plan could be installed in small groups or departments, as well as in the entire inspection department. A plan of this kind is discussed later in the paper.

In many plants, the number of inspectors required is determined by the number of productive workers. This method seems to disregard the amount of actual inspection required on the individual parts; consequently, these ratios and percentages are frequently meaningless. An analysis of the time required to inspect the various parts entering into any given unit would seem to give the most reasonable and practical data concerning the number of inspectors required for its production. Percentages and ratios of direct to indirect labor cannot be determined by rule-of-thumb methods. It has been noted, in some plants having an unusually large overhead, that manufacturing costs are very low, while other shops manufacturing the same product with a lower percentage of indirect workers have a high manufacturing-cost. The actual number of inspectors should be determined by a very thorough study of each department and on a scientific job-analysis basis. Management often insists that the percentage of indirect workers, of which inspection is a part, is too high for the number of productive workers on the pay-roll; and its conclusions will be justified until we can show something constructive in the way of standardization that will be substantial proof to the contrary.

Why Inspection Is Classified as Indirect Labor

Just why inspection is classified as indirect labor is sometimes hard to understand. Indirect workers of the inspection division are as essential to production as are machine operators; and without them manufacturing would fail to function. Although it is true that an inspector does not actually produce, he forms a part of the producing element that ultimately is responsible for the final finished product and therefore has a part in the production of that particular unit. In the cylinder-block-inspection plan discussed further on, inspection is tied up so closely with production that it would be some trouble to segregate it as indirect. Inspection, as applied to manufacturing, does not come under the same classification as clerks, office help and the like but comes within the scope of actual manufacturing.

From the foregoing it can readily be seen that the majority of the phases of inspection work can be analyzed to determine with approximate certainty the actual number of inspectors required for the economical and quality production. The saving that can be effected in material, the safeguarding of quality, the prevention of waste, and suggestions for more economical methods play a very important part in manufacturing and can probably be put on some kind of incentive basis that will be an extra reward for extra effort.

Although practically all direct labor in the automotive industry has been subjected to the closest scrutiny of industrial engineers selected for the purpose, and very substantial savings have been made in reducing labor costs, the so-called indirect workers have been more or less overlooked, and it is reasonable to assume that proportionately as great savings can be made in this division of manufacturing. Some improvement has been made in the output per man-hour of inspection but the gain has been almost negligible in contrast with the gain in production.

Most industrial plants, and certainly all automobile plants, have a certain amount of inspection work that is constant and repetitive. One instance is the inspection of piston-pins. Each pin must be inspected for diameter, hardness, and the like. With such jobs we have found that time-studies are invaluable.

Inspection of Cam-Rollers

A time-study of our cam-roller inspection brought about a considerable final saving. A description of the methods now used follows. Fig. 1 is a sketch of the roller; Fig. 2 is the routing-sheet. The rollers are received while covered with oil for rust-prevention purposes and, as the first operation, are washed by placing a number of rollers in a bucket having numerous small holes punched in the bottom. The bucket is then dipped into gasoline and vigorously shaken to allow all portions of the surface of the rollers to be washed. A number of other methods of washing have been tried, but that with

gasoline seems to be the best, as it does not heat the rollers or leave a deposit. The hourly production is 8438.

The rollers are then taken to the inspection bench and are placed on a rod so that the outside surfaces can be wiped off with one or two sweeps of a rag and can be carefully examined for surface defects. They are then laid in wooden V-blocks, to keep them in an orderly arrangement preparatory to handling in the next operation. The hourly production is 2259.

The next operation, checking the bore and classifying for size, is the most important and perhaps the most interesting. The operator first takes a handful of rollers in orderly arrangement from the V-block and runs a swab through the entire handful. The rollers are then placed one at a time upon a special direct-reading dial-gage, which is shown in Fig. 3. The rollers are here classified for diameter of bore and are checked for roundness as well as for being within the specified limits of size. This gage consists of one stationary and one movable measuring-point, both of which are approximately half-circles, having a diameter slightly smaller than the diameter to be checked. This results in line-contact, when the spring forces the two points apart, and holds the measuring-points against the walls of the bore at constant pressure. With line-contact of this type, the measuring-points would speedily wear to the radius of the part to be measured and the measuring-line would become broad and destroy the accuracy of the indications. The greatest part of this trouble is avoided by hollow-grinding the reliefs on the

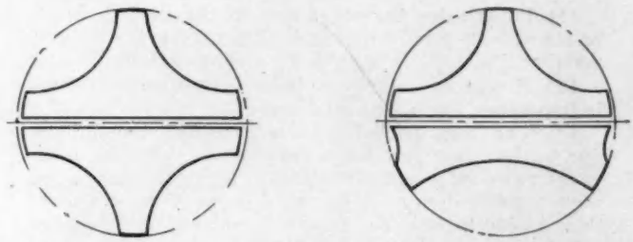


FIG. 4—CROSS-SECTIONS OF THE MEASURING-POINTS WHEN ARRANGED FOR BOTH TWO-POINT AND THREE-POINT CONTACT

The Movable Measuring-Point Is Pressed into One Member of a Rather Large Frictionless Bearing. The Gage Is Set by a Standard and All Readings Are Comparative. Due to the Line-Contact, It Is Necessary Only To Revolve the Object To Be Measured in Order To Measure the Amount of Out-of-Roundness

measuring-points, an operation that controls the wear to a certain extent. Fig. 4 shows cross-sections of the measuring-points when they are arranged for both two-point and three-point contact. The movable measuring-point is pressed into one member of a rather large frictionless bearing. The gage is set by a standard and all readings are comparative. Due to the line contact, it is necessary only to revolve the object to be measured in order to determine the amount of out-of-roundness.

SUPERIORITY OF THE DIRECT-READING TO THE PLUG-GAGE METHOD

The direct-reading method is far superior to the plug-gage method, for the following reasons:

TIME STUDY RECORD

Form 1032 3M 1-26 Ideal 210

DATE 7-9-26 PART NO. 12394

NAME OF PART Valve Lifter Roller MAT'L SAE #1020 OPER. NO. 3

DESCRIPTION OF OPER. Inspect I.D. for size .491–4915 MACH. NO. Bench

PLUG GAGE METHOD OPERATOR Stone DEP'T NO. Inspection

SUB-OPER.	TOOL NUMBER	NAME OF TOOL
		Inspection Bench
		(1) Plug Gage & Holder .491"
		(1) " " " " .4915"

TOOL SET-UP

TIME PRICE

FLAT TIME PER PIECE .16

TOOL ALLOWANCE PER PIECE

TOTAL TIME PER PIECE .16

60 ÷ .16 = 375 NO. PC'S PER HOUR

90 % OF 375 = 337 PC'S ON WHICH TO SET PRICE

÷ = PRICE OF PIECE

BASE RATE PRICE PER 100 =

	SUB-OPERATIONS	SPEED	FEED	DEPTH CUT	LINEN CUT	FEET MIN.	ACTUAL TIME TAKEN	AVER.
1	a. Swab out inside diameter						16.00	
	b. Inspect roller with .491" gage							
	c. Inspect roller with .4915" gage							
	NOTE:- Time shown per 100 rollers							
		TOTAL						

PREVIOUS PRICE LUBRICANT BRINNEL

REMARKS: SCLERISCOPE

SIGNED JEN APPROVED APPROVED

FIG. 5—VALVE-LIFTER ROLLER INSPECTION; PLUG-GAGE METHOD

The Flat Time Per Piece Is 0.16 Min., or 375 Pieces Per Hr. The Price Is Set on 90 Per Cent of This Number, or 337

(1) It indicates the exact size of the part in increments of 0.0001 in., whereas a plug-gage indicates only whether the part is within or without set limits.

(2) It tells how much the hole is out-of-round, which is impossible to do with plug-gages.

(3) The measuring-points last almost indefinitely, due to the construction described above, whereas plug-gages wear out rapidly. Our records over a long period show the life of plug-gages on this job to be not more than 12,000 holes. The measuring-points on this gage will last for at least 1,000,000 holes, with occasional hand-stoning to readjust the side-clearance when the wear has decreased it. This stoning requires approximately 5 min.

(4) The human element does not enter.

(5) By actual time-study, this method is two and one-third times as fast as the plug-gage method.

The hourly production on this operation is 659.

Comparative time-studies of the plug-gage and the indicator methods are shown in Figs. 5 and 6.

Hardness testing comes next and is performed by scleroscoping the roller at four points on the outer surface. A V-block fixture with a lateral stop is used to hold and to locate the roller and allows rapid loading and unloading. The scleroscope is operated by a foot-pedal and leaves both hands free. The foot-pedal method was found to be 30 per cent faster than the hand-bulb method.

An important item of accuracy in valve-timing and quietness of operation is the concentricity of the outer surface and the squareness of the sides. Usually a 10-per cent inspection of these items is sufficient and is accomplished on the special bench-centers and triple indicator shown in Fig. 7. The method of operation is evident. The roller is placed on the mandrel, then in the centers and is revolved, with an indicator on each side face and another on the outer surface. The hourly production is 221. The last operation, the gaging for thickness on an amplifying-gage, is usually required on only 10 per cent of the parts.

Why Time-Studies Are Valuable

The justification of time-studies perhaps requires some explanation inasmuch as no wage-incentive is used. We have found at least five reasons for using them.

(1) Each inspector knows that a certain amount of work is expected of him. A man will produce more work when given a definite assignment than when working more or less at random; besides, he knows that his output will be checked.

(2) The foreman can check the inspector's output daily and, inasmuch as an accurate count is unnecessary, the foreman's daily check of the number of pieces inspected is rapid and economical. The system demands merely a number of stock or tote-boxes, which contain a known amount of stock, and the periodic removal of the completely inspected material in filled boxes.

(3) The chief inspector can check the output of a department over any given period with very little trouble. This is done by adding the approximate inspection-department inventory at a given date to the material shown by the shop records as having been delivered to the department, and subtracting the approximate inventory at the time of the check. The amounts obtained can be checked against the number of man-hours required and the time-studies.

(4) It draws the attention of everyone concerned to the possibility of economizing by better methods, mainly by impressing upon him the extreme slowness of some operations.

(5) It is of assistance in planning the work, for the length of time necessary to keep an inspector on a job,

Form 1032 3M 1-26 Ideal 230

TIME STUDY RECORD

DATE 7-16-26 PART NO. 12394

NAME OF PART Valve Lifter Boiler MAT'L SAE #1020 OPER. NO. 3

DESCRIPTION OF OPER. Swab I.D. of roller & inspect I.D. for size & roundness MACH. NO.

DIRECT READING INDICATOR METHOD OPERATOR DEP'T NO. Inspection

SUB. OPER.	TOOL NUMBER	NAME OF TOOL
		Inspection Bench
		Special Direct Reading Gage – .0001
		Small Swab
		Holding Fixture for rollers

TOOL SET-UP

TIME PRICE

FLAT TIME PER PIECE .0683

TOOL ALLOWANCE PER PIECE

TOTAL TIME PER PIECE .0683

60 ÷ .0683 = 878 NO. PC'S PER HOUR

90 % OF 878–790 PC'S ON WHICH TO SET PRICE

÷ = PRICE PER PIECE

BASE RATE PRICE PER 100 =

	SUB-OPERATIONS	SPEED	FEED	DEPTH CUT	LENGTH CUT	FEET MIN.	ACTUAL TIME TAKEN					AVER.
1	a. Swab inside diameter of rollers							10.24				
	b. Place roller on gage and inspect I.D. size & sort .491–.4915											
	NOTE:–Time shown per 150 rollers											

Fig. 6—Valve-Lifter Roller Inspection; Direct-Reading Indicator Method

The Flat Time Per Piece Is 0.0683 Min., or 878 Pieces Per Hr. Ninety Per Cent of This Number, on Which the Price Is Set, Is 790. This Method Is Therefore Two and One-Third Times as Fast as the Plug-Gage Method

to produce a given amount of work, is known beforehand.

In this day of mechanical gaging-devices, there is no more reason that time allotments should not be made for some classes of inspection than for a production operation. A certain amount of judgment, however, must be used in selecting jobs that will respond to this treatment economically.

I have never approved of the system of covering the inspection of every part of the car with definite inspection routing sheets, for they do not seem to be economically applicable to every part and to every method of manufacturing. During times of more or less trouble it is necessary to inspect every operation of comparatively little importance; to continue this costly inspection after the trouble has been cared for is certainly not economical. This is particularly true in the case of parts purchased outside. A certain vendor's method of manufacturing may be sufficiently uncertain to demand 100-per cent inspection on certain operations. It does not necessarily follow, however, that when these parts are procured from another vendor the same 100-per cent inspection will be required. The most economical method seems to be an inspection based partly on the importance of the various dimensions and partly on the general accuracy of each dimension as produced by the various vendors.

Production-Line Inspection

Another method of allotting a fairly definite time-interval for a given inspection is to adapt the inspection to a station in the production line with a definite inspection-specification balanced in time with the production operations.

In some plants, it is the practice to Brinell-test, 100 per cent, large castings, such as cylinder-blocks and crankcases in the rough, previously to delivering them to the machine line. A few plants have adopted the method of using a small-percentage hardness-inspection in the rough as a precheck and have mounted a Brinell machine in the conveyor line in such a manner that it is possible, without extra handling, to test each cylinder as it reaches the testing-machine. The screw of the Brinell machine is located at a suitable opening in the conveyor, such as between the rollers in a roller conveyor. When the cylinder in its natural course reaches the proper point, the hand-wheel is turned, lifting the cylinder-block free of the rollers and pressing it against the Brinell ball in the usual way. When this test is placed just beyond the milling operation, there is a saving of the grinding operation for testing, as well as of the expensive handling incident to the test.

In one Detroit plant, a continuous chain-conveyor is used for the assembling of instrument-boards, that is, for the placing of the instruments, the wiring and the like. The last of about 12 stations is occupied by the inspector, who has a certain number of items to inspect, and the operation is well balanced with all the remaining operations. It seems that the mere fact of making this inspection on the conveyor has speeded-up the operation to a point at which the inspector does about double the work that would normally be expected, if it were done over a bench.

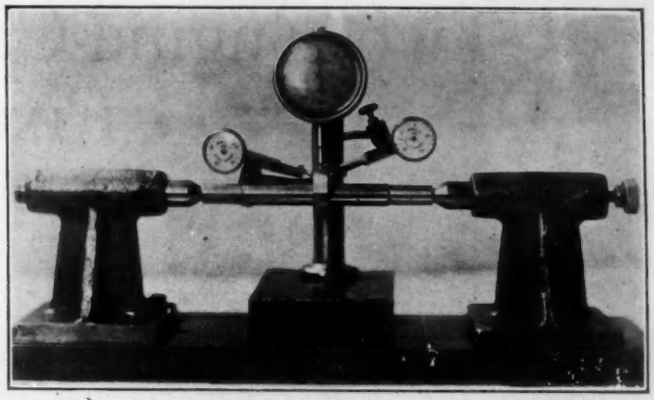


Fig. 7—Special Bench-Centers and Triple Indicator for Checking the Concentricity of the Outside Diameter and the Squareness of the Sides

The Roller Is Placed on the Mandrel, Then in the Centers, and Is Revolved, with an Indicator on Each Side Face and Another on the Outside Diameter. The Hourly Production Is 221

Speed of Inspection versus Care

In the case of our own finish-machined cylinder-block inspection, we are making plans to incorporate an inspection station at the end of the line, with the operations balanced against the machine operations. It is planned eventually to put the inspector in the group. This will assure his working fast enough; but the big problem will be to make him careful enough. There seems to be two ways open to accomplish this result. He might be penalized heavily for anything that gets by him or he might be paid a bonus for rejections. The objection to a penalty for passing poor material is the fact that, normally, all the poor material would not be caught, and the inspector might take many risks to increase his earnings. If he were paid a bonus for rejections, the bonus would have to be considerably higher than the price per block passed. His tendency then might be to reject all blocks possible; but this could be cared for by having his rejections gone over by the machine-shop inspection-foreman or the salvageman and paying a bonus only on blocks, the rejection of which was upheld. Inasmuch as it is common practice to have rejections checked by a higher authority than the line inspector, no additional cost would be involved.

It seems probable that a station of this kind could eliminate at least some of our present machine-inspection as well as speed-up the final inspection. In the case of setting-up, the first block could be brought to the station for approval, for there would be a gage for every operation at this point. We believe that operators would be more inclined to direct the inspector's attention to what they thought questionable, for they would know that someone at the end of the line would reject poor work and the group earnings would be cut down accordingly. At present, there are 17 inspection operations. Many problems, no doubt, remain to be solved in getting this idea to work, but the apparent saving makes the effort well worthwhile.

Two Engine-Casting Inspection Fixtures

By A. R. Fors[1]

PRODUCTION MEETING PAPER *Illustrated with* PHOTOGRAPHS

ABSTRACT

ONE of the fixtures illustrated and described is used for checking unit cylinder-and-crankcase blocks to assure that the castings will be machined correctly. This fixture is used in pairs, one at the foundry and the other where the first milling-operation is performed and where the blocks are checked a second time before they start through the machining line. The blocks are located in a horizontal plane on three fixed locating-points in the foundry fixture, but the same points are adjustable in the fixture used in the machine-shop, where the amount of adjustment needed to correct a slight bore-shift is marked on the casting. Other locating points are provided and hardened-steel strips on the base of the fixture locate various templets with correct relation to the locating points. Templets are provided for top, bottom, ends, and sides of the castings. These check the location of cores for cylinder-bore, valve-seats, camshaft bearings, and intake and exhaust ports; cylinder-wall and water-jacket thickness; bosses to be drilled; and finish allowance on bores for the crank, cam and pump shafts and main bearings, and all other surfaces to be machined.

The other device is a gage for checking the depth of combustion-chambers in cylinder-head castings to assure that they will have equal volumetric capacity and to eliminate the expensive operation of machining them. This fixture also is used in pairs. The gage is located in two of the combustion-chambers by fixed points and by a fulcrum to give three-point location. Two other points locate in the valve side, and other points give side and end location of the casting. All chambers are then checked in relation by two spring-plungers in each chamber, each plunger having a pointer that registers on a graduated scale. A variation of plus or minus 0.015 in. is allowed.

A CYLINDER-AND-CRANKCASE block is the most expensive material-unit in an engine and also represents one of the largest direct-labor units; therefore it is most economical to have a casting that will machine correctly through the machine lineup. A fixture for the purpose of assuring such castings is shown in the accompanying illustrations.

One such fixture is supplied to our foundry that casts the blocks. Another fixture is located at our first milling-operation, where the block is checked again before it starts through the machining line.

Fig. 1 shows the base of the fixture, with the locating points indicated. The points have the same location and size as those on our first milling and drilling fixtures. The block is placed on points *A*, *B* and *C*. This is a three-point location in the horizontal plane. The foundry fixture is made with solid points, whereas the machine-shop fixture has points which can be adjusted so that the casting will be machined correctly. The amount of adjustment needed to correct a slight core-shift is marked on the block at the point where the correction is required, and the first milling-fixture, which has a similar adjustment, is set to correspond with the machine-shop fixture.

Points *D* and *E* locate under the water-jacket for side location of the block. Clamps *F* and *G* are provided to ensure the cylinder being against the locating points. A spring V-equalizer, *H*, locates between the two center cylinder-barrels and assures a uniform cylinder-wall thickness. Hardened-steel strips locate the templets in relation to the locating points.

In Fig. 2 a block is shown in position on the fixture base. Front and end templets are seen in position in Fig. 3. The front-end templet checks the finish allowance in the bores for the crank, cam and pump shafts and also all other surfaces to be machined. It also checks the location of bosses to be drilled and the outside diameter of the front camshaft-bearing. The steel plate bolted to the top templet in this view is used to check the location of cores of the intake and exhaust ports.

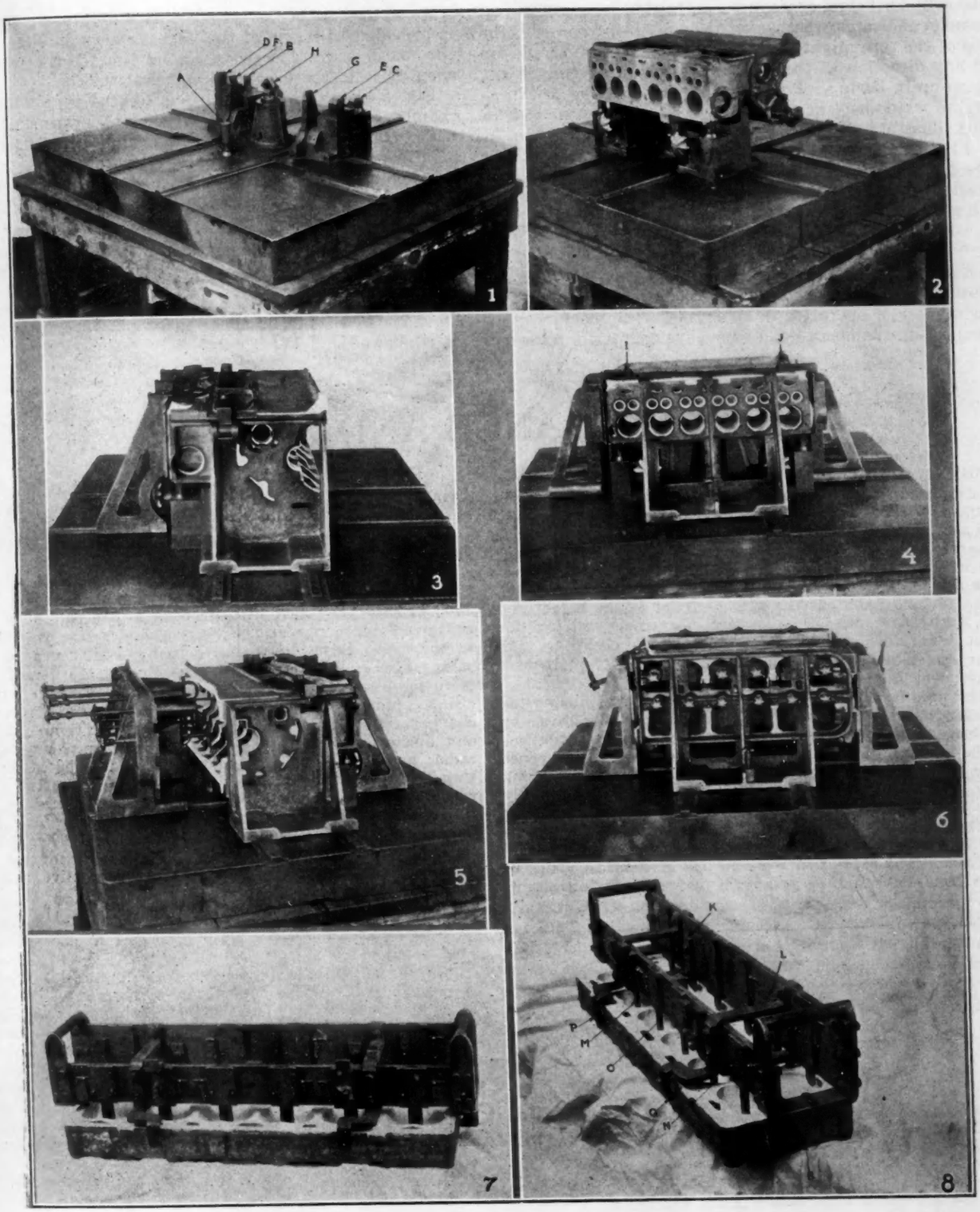
The top templet, which checks the location of cylinder-bore and valve-seat cores, is shown in Fig. 4. This templet also checks the water-circulation cored holes. Plungers *I* and *J* check the wall thickness of the cylinder-barrels.

The rear-end templet, seen in front view in Fig. 5, checks the finish allowance in the rear crankshaft and

[1]M.S.A.E.—Production engineer, Continental Motors Corporation, Detroit.

THE ENGINE-BLOCK CHECKING FIXTURE AND THE COMBUSTION-CHAMBER DEPTH GAGE IN USE

Fig. 1 Is the Main Base of the Engine-Block Checking Fixture, the Various Parts Being the Locators for Three-Point Horizontal Location, *A*, *B* and *C*; the Side-Locating Points *D* and *E* and the Clamps *F* and *G* To Force the Casting against Them; the Spring Equalizer for End Location *H*; and the Four Sets of Hardened Strips for Locating Templets to the Base. In Fig. 2 a Crankcase and Cylinder-Block Are Shown in Position on the Fixture. The End-Locating Point Can Be Seen at the Right Center and the Adjustable Locators under the Right and Left Corners of the Casting. Fig. 3 Shows the Front-End and Top Templets in Position. The Former, Shown in the Full Front View, Checks the Bores of the Shafts, the Bosses and the Outside Diameter of the Front Camshaft-Bearing. The Side of the Top Templet Is Seen at the Left and the Steel Plate That Is Bolted to It Is Used for Checking the Location of the Intake and Exhaust-Port Cores. The Templet for the Top of the Cylinder-Block, Which Is Shown in Fig. 4, Checks the Location of the Cylinder Bore and Valve-Seat Cores and the Water-Circulation Cored Holes, the Wall Thickness of the Cylinder-Barrels Being Checked by the Plungers *I* and *J*. In Fig. 5 the Use of Rear-End and Bottom Templets Is Illustrated. The Former, Which Is Seen at the Front, Checks the Finish Allowance in the Rear Bores for Crankshaft and Camshaft and on the Bearing Slot and Oil-Pan Contact. The Bottom Templet, Seen at the Left Checks the Two Center Camshaft-Bearing Bores and the Bottom of the Cylinder-Barrel Cores. The Plungers for Checking the Thickness of the Water-Jackets at the Spring-Seats Are Shown in Their Withdrawn Position. Fig. 6 Shows the End of the Templet for the Bottom of the Block with the Various Plungers Pushed into Position. Sight Gages Are Provided for Checking the Finish To Be Allowed on the Sides of the Main Bearings. One of the Gages for Checking the Depth of Combustion-Chambers, Which Is Illustrated in Fig. 7, Is Provided for the Foundry and the Machine-Shop Has Another for Double Checking. When in Use the Gage Is Set on the Inverted Cylinder-Head Casting as Shown with Two Locating-Points in Each Combustion-Chamber. The Various Locating Points of the Combustion-Chamber Gage Are Shown in Fig. 8. *K* and *L* Are the Fixed Locators for Chambers No. 2 and 5, and *M* and *N* Are the Points for Locating the Valve Side; *O* Being a Fulcrum To Give Three-Point Location. The Two Side-Location Points Are *P* and *Q* and *R* Is the End-Location Point. All Chambers Are Checked in Relation by Two Spring-Plungers in Each Chamber, and a Plunger, Which Can Be Seen More Clearly in Fig. 7, Registers the Variations on a Graduated Scale on the Side of the Gage


A
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8

camshaft bores as well as the finish on the bearing slot and oil-pan contact. At the left in this illustration the bottom templets for checking the two center camshaft-bearing bores and the templet for checking the bottom of the cylinder-barrel cores are seen in side view. This last templet indicates whether there is a tip in the core; the top of the core might show true but if the core should tip in any direction at the bottom the inaccuracy might not clean-up in boring. Plungers for checking the thickness of the water-jackets at the spring-seats are also seen in this illustration.

Fig. 6 shows in full front view the templet for checking the bottom of the block, with the plungers pushed into position. Sight-gages are provided for checking the finish to be given on the sides of the main bearings.

Gage for Checking Combustion-Chambers

Equal volume in combustion-chambers is one of the essentials required for obtaining the correct power and smoothness of operation in an engine. The machining of combustion-chambers is an expensive operation, however, because of the equipment required and the direct cost of labor and tools. To eliminate this machine work we insist that castings shall be accurate and have designed a gage to assure such accuracy.

As in the case of the cylinder-block fixture, the foundry is provided with one of the gages, shown in Fig. 7, and the castings are checked a second time in the machine-shop prior to the first milling-operation.

Fig. 8 shows how the gage is located in combustion-chambers Nos. 2 and 5 by a three-point location. Points *K* and *L* in the dome of these two chambers are fixed, and points *M* and *N* operated by a fulcrum at *O* to give a three-point effect, locate in the valve side. The gage is located for side location by points *P* and *Q* and for end location by point *R*. These same points are used in the first milling and drilling operations.

All chambers are then checked in relation by two spring-plungers in each chamber. Attached to each plunger is a pointer with a 5-to-1 ratio that registers on a graduated scale. A variation of plus or minus 0.015 in. is allowed.

LIFE INSURANCE AND SAVINGS

THIS era in American industrial history, marked by unexampled prosperity among the wage earners of the country, is characterized by liberal spending on both necessities and luxuries. Hence, the charge of extravagance in our general scale of living is frequently made. However, signs are noticed also of conservatism and determination to provide for rainy days. This often develops in the individual, when fortune pulls out the spigot of the money barrel and lets wealth flow into his lap, a certain psychological fear for what the future may have in store and a desire to take some systematic means of making his prosperity permanent comes over him.

That this is true at present and has been true during the period of large business activity and high wages is shown by the increase in life insurance sales that has been taking place in the last 2 or 3 years. The writings of new life insurance were 5.5 per cent greater in May of this year than during May of 1925. The total for the month was substantially over $1,000,000,000. In the first 5 months of the year, new life insurance of all classes amounted to $4,705,282,000, which was 10.7 per cent more than for the corresponding period last year. The rate of increase in life insurance policies in force from 1900 to 1910 gained 58 per cent per inhabitant, and from 1919 to 1920 this gain was 115 per cent. From 1920 to the present the gain was 104.5 per cent, or at the rate of 209 per cent for 10 years. This is in accordance with a recent estimate of the National Industrial Conference Board.

While individual deposits in savings banks in the United States increased 40 per cent per capita in each decade from 1900 to 1920, they have been growing at the rate of 55 per cent per decade since 1920. The progressive rate of increase in these two forms of saving deposits, life insurance and savings bank, is, according to the Conference Board, the more significant because they have been accompanied with a rising standard of living during a time when the automobile changed from a rare luxury to an almost everyman's utility and during a period when such articles as phonographs, radios and telephones were more widely distributed in the United States than in any other country on earth. The wholesale value of passenger automobiles produced in the United States annually is taken as an instance. This rose from 6 cents per capita of total population in 1900 to $21.77 per capita in 1925, while total per capita savings during the same period accumulated at a rapidly progressive rate of increase.—*Bache Review.*

Laboratory Technique, Methods and Equipment

By FERDINAND JEHLE[1]

MILWAUKEE SECTION PAPER *Illustrated with* CHARTS AND PHOTOGRAPHS

ABSTRACT

IN undertaking any experimental work the first step is to plan carefully each successive step. Literature bearing on the subject should be examined to learn what work others have done on the problem and avoid needless duplication of effort. If the testing of only a simple accessory is involved, the results the device is intended to accomplish should be studied and an effort made to discover the designer's reason for believing that it will accomplish them. All conditions under which such a device must operate should be listed and the information needed from which to draw conclusions as to whether the device will meet them successfully should be determined. Before starting the actual work of testing, it is good policy to plan the necessary charts for presentation of the report.

This preliminary work means that the investigator will start well prepared but not with his mind made up as to what the results will be. It is necessary to be very careful in all experimental or research work; otherwise preconceived ideas are likely to result in finding what one wants to find rather than the exact truth. Prejudice is not the result of careful thinking and planning but of lack of such forethought. If a problem involves the investigation of a device on an engine, as for example a manifold, it is well to remember that there are other functioning parts and to be on guard against the temptation to attribute a sudden falling off of engine-power to the manifold when it may, in fact, be due to improper functioning of one of the other parts. New problems are more than likely to arise within the major one as the work progresses and must be solved before the original program can be continued. Each sub-problem should also be planned carefully.

Methods to be followed in making an investigation are elucidated by examples of a study of adapting an existing carbureter to an existing engine and of a study of charge distribution by a manifold to the cylinders of a four-cylinder engine. It is necessary to do this with the use of numerical quantities taken from actual test results, but in the case of the carbureter tests the figures have no actual relation to one another and are not to be taken as representing achievements, as many were taken from experimental engines and other equipment. Before the effect of a given carbureter on the power and fuel economy of an engine can be studied, it is first necessary to learn what the engine is capable of doing when it is not influenced by the characteristics of the carbureter. After charts have been prepared from the ascertained data, the commercial-carbureter tests can be started. Each step for carrying these out is explained. All results are plotted in various ways for comparison and study.

A method that is thought to be easiest and surest for studying charge distribution is by measurement of the maximum explosion-pressures in the several cylinders of a multiple-cylinder engine. The equipment used and the method of doing this are described and the results given. Curves produced from the study indicate that power loss due to poor distribution is incurred by reason of (*a*) too lean or too rich a mixture and (*b*) improper spark-advance.

In planning the layout and equipment of a laboratory, a good way to begin is to make a study of the work that probably will have to be done in it and to realize that undoubtedly some problems will have to be undertaken that are not included in the survey, for which reason all equipment should be so designed that changes can be made easily, quickly and cheaply. Known essentials are that

(1) Equipment must be bolted to the floor
(2) Water must be drained away
(3) Sufficient working space must be available
(4) The entire space must be well lighted
(5) The room should have a high ceiling
(6) Good crane-transportation should be provided
(7) Provision must be made for conducting away exhaust-gas

A model laboratory that answers all of these requirements is illustrated and described in considerable detail.

NO better introduction to a paper on research or experimental work can be given than the following quotation from Dr. Arthur Gordon Webster regarding experimental work:

> The proper order of procedure may be stated: Think, calculate, plan, experiment, think—and first, last and all the time, THINK. The method often pursued is: Wonder, guess, putter, guess again, theorize, and above all avoid calculation.

The first step in undertaking any experimental work is to plan every step carefully. Make a careful bibliography to learn what work others have done on the same problem to avoid unnecessary duplication. Even if the problem involves only the testing of a comparatively simple accessory, study carefully what the device is supposed to do and discover the designer's reason for believing that it will do it. Make a list of all the conditions under which such a device must operate and determine what information is necessary to draw conclusions as to whether or not the equipment will meet such conditions successfully. It is a good policy to plan the necessary

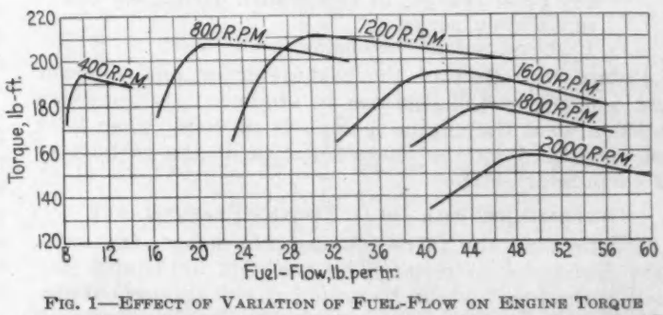


FIG. 1—EFFECT OF VARIATION OF FUEL-FLOW ON ENGINE TORQUE
These Curves Give a General Idea of the Maximum Torque and Torque Variation That May Be Expected of the Engine at Different Speeds Due to Variation of Fuel-Air Ratio but Do Not Give Any Real Idea of Fuel Economy

[1] M.S.A.E.—Research engineer, White Motor Co., Cleveland.

charts for the presentation of the report before starting the actual work of testing.

Giving all this thought to the problem and forming a picture of the entire procedure do not mean that the investigator starts work with his mind made up as to what the results will be. They merely mean that he is starting well prepared. If, as has happened, an experimenter starts out to *prove* the answer to a problem or the merits of a device, he is prejudiced, and this prejudice is not the result of careful thinking and planning; it is due rather to the lack of forethought. In any experimental or research work, it always behooves one to be very careful or he is likely to find exactly what he wants to find. For example, if the problem at hand is the investigation of manifolds, it is well to remember that the engine which is being used for the work has a carbureter, an ignition system, valves, and other functioning parts and that while the temptation to attribute a sudden loss in power to the manifold under test may be great, the reason may be the improper functioning of one of these other parts.

While all laboratory work should be planned so that a definite program can be followed, it is more than likely that, as the work progresses, new problems will arise within the original one and very often these must be solved before the program can be continued. Each subproblem encountered should, however, also be carefully planned.

Methods can be described best by illustration of the handling of several problems. Unfortunately, it will be necessary to do this with the use of numerical quantities. The figures were taken from test results but were chosen with a view toward illustrating the method and therefore should not be interpreted as representing achievements. Most of the engines and other equipment used were experimental, and many of the quantities given as illustrations were taken from different equipment and consequently have no relation to one another.

A Study of Carbureters on a Given Engine

The first example is an investigation of carbureters rather than a study of the laws of carburetion; that is, the problem of adapting an existing carbureter to an existing engine.

Several objects which a carbureter should accomplish and which must be studied are

(1) It should permit the engine to develop its maximum power at all speeds within its operating range
(2) This maximum power should be developed at as low a fuel consumption as is safe
(3) The carbureter should give economical operation at less than full engine-load
(4) It should permit good acceleration, and acceleration should be smooth, that is, there should not be any great changes in acceleration during any one accelerating period
(5) It should permit the engine to idle well

Before the effect of the carbureter on engine-power and economy at full load can be studied, it is necessary to learn what the engine is capable of doing when it is not influenced by the characteristics of the carbureter or carbureter setting.

Determining the Ideal Engine-Performance

To determine the ideal engine-performance, the ordinary carbureter is replaced by one with adjustable jets so that the fuel-flow can be varied at will throughout the entire mixture-range. The engine is run successively at different speeds, say 400, 800, 1200, 1600, 1800, and 2000 r.p.m. Power readings are taken at each of these speeds with different ratios of fuel and air throughout the mixture range. The rate of fuel-flow is varied so that the engine-power will fall off due to too lean a mixture at one stage and to too rich a mixture at another stage. The results are then plotted, as in Fig. 1, which shows the general character of the results obtained by plotting the engine torque in pound-feet at these various readings against the fuel consumption in pounds per hour of fuel-flow. This chart gives a general idea of what can be expected of the engine as to maximum torque and torque variation due to variation of mixture strength, but it does not give any real idea of fuel economy. It is necessary, therefore, to recalculate these curves and plot them for brake-horsepower against specific fuel-economy, that is, pounds per brake-horsepower-hour. This also is done for each engine speed. The resulting curves are shown in Fig. 2. A horizontal line drawn tangent to any one of the curves will intersect the axis of the ordinate at the point of maximum power for the engine-speed to which the curve relates. Dropping down to the axis of abscissas from the point of tangency, the specific fuel-consumption required for developing maximum power at that speed can be read. A vertical line tangent to any one of the curves will, at its point of tangency, show the power developed at maximum economy and the specific consumption for that power.

A point at each speed that shows the desirable performance of the engine for that speed can now be selected. The maximum-economy point cannot be chosen because the power is reduced considerably at that point and, should the engine for any reason be supplied with slightly less fuel than is necessary, the power would drop off very fast; in fact, the engine might stall. A point must therefore be chosen somewhere in the neighborhood of maximum power and at such a location that, should the fuel-flow be slightly increased or slightly decreased, the effect on engine-power would be small. After selecting a series of such points, a line can be drawn through them, as shown by the dotted line on Fig. 2. This can be called the line of selected performance of the engine and can easily be re-plotted in its usual form of characteristic engine-curves. The solid lines on Fig. 3 represent this selected performance plotted in torque, brake-horsepower and specific fuel-consumption curves. To this has been added another valuable curve, that of total fuel-consumption at each speed.

Determining a Carbureter Setting

Having thus determined the engine performance, the commercial-carbureter tests can be started. Another set of curves, shown by dotted lines, has been added to Fig. 3. These represent the engine performance with a definite carbureter-setting. It will be noticed that the torque and horsepower curves have been duplicated closely. The curve for total fuel-consumption, however, does not approach the selected curve very closely. The mixture is much richer at the lower speeds and very much leaner at the higher speeds. The total fuel-consumption has been reduced from the selected 50.5 lb. per hr. to 46.5 lb. per hr., which brings the fuel economy from 0.87 lb. per b.hp-hr. to 0.80 lb. per b.hp-hr. The horsepower has been reduced from 59.5 to 58.5. It might seem that a reduction of only 1 hp. for a saving of 0.07 lb. per b.hp-hr. in fuel consumption, or a saving of 4 lb. per hr., would not be a bad sacrifice. Fig. 2, however, tells a different story. At 2000 r.p.m. and a fuel economy of 0.87, the engine was operating on a slightly richer mixture than was necessary for maximum power. However, the mixture ratio is on the safe side

of the peak and a slight difference in fuel-flow, be it toward the richer or toward the leaner side, would make very little difference in engine-power. The effecting of this saving of 0.07 lb. per b.hp-hr., that is, reducing the specific consumption to 0.80 lb., moves the point of engine operation below the point of maximum power on the lean side and at such a position on the curve that, if the fuel-flow should be slightly reduced, the power and engine performance would fall off with extreme rapidity; that is, the engine would be operating on a rather unstable part of this curve. At 400 r.p.m. the specific fuel-consumption was increased from 0.67 to 0.72 lb. per b.hp-hr. Referring to Fig. 2, it is seen that this change involves a slight loss in power and a large increase in fuel consumption, while absolutely nothing is to be gained by it, since the engine is already operating on a perfectly safe

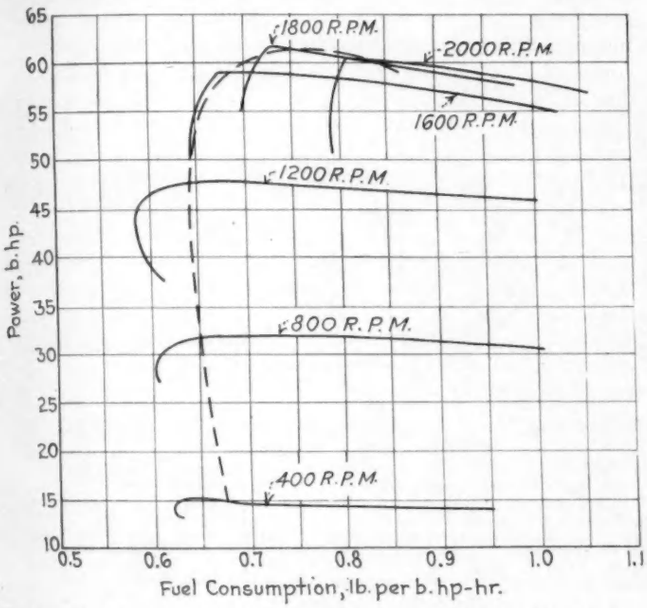


FIG. 2—POWER AND SPECIFIC FUEL-CONSUMPTION AT DIFFERENT ENGINE-SPEEDS

Here the Curves in Fig. 1 Are Recalculated and the Brake Horsepower Is Plotted Against Specific Fuel-Consumption for Each Engine-Speed. A Point at Each Speed That Shows the Desirable Performance of the Engine for That Speed Can Be Selected, as Indicated by the Dotted Line

portion of the curve. At 800 and 1200 r.p.m. the same is true, although to a less marked degree. The dotted line, therefore, does not represent a really good carbureter-setting. The curve of total fuel-consumption must be more nearly duplicated.

It is well to make a thorough study of the fuel-flow through different carbureter jets and adjustments at different engine-speeds before determining a setting. The results of this finding should be kept and plotted carefully. Fig. 4 shows the curves of such a series of tests. The results are plotted for different sizes of both main jet and compensator jet. It will be seen that the rate of fuel-flow through the compensator jet is in no way affected by the engine-speed. The flow through the main jet, on the other hand, is greatly affected by the speed. In order to draw the curves properly, it is necessary to use jets both much smaller and much larger than the jet that will be required to give the best engine performance. To obtain the first points, the engine can be run with only a main jet and then with a compensator jet added. The flow through the compensator jet can be determined by noting the difference in flow through the main jet and flow through both main and compensator

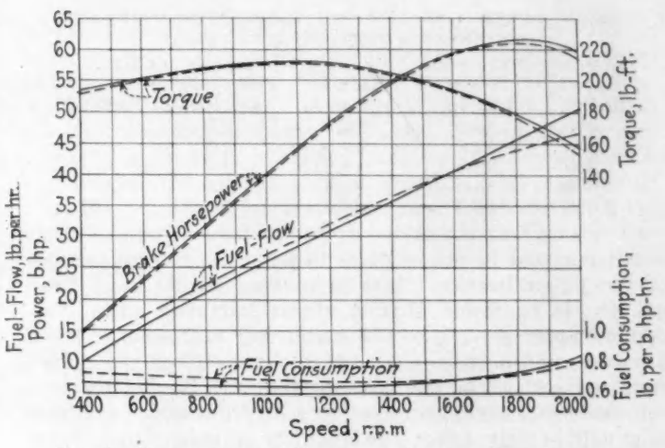


FIG. 3—CHARACTERISTIC CURVES OF ENGINE PERFORMANCE

The Solid-Line Curves Represent the Selected Performance, as Indicated in Fig. 2, Plotted in Torque, Brake-Horsepower, Specific Fuel-Consumption, and Total Fuel-Consumption Curves. The Dotted-Line Curves Represent the Engine Performance with a Definite Carbureter-Setting, Which Does Not Result in any Desirable Gain

jets. Many combinations will have to be run in order to obtain the information necessary to draw the curves. By comparing the jet-calibration curves with the total-fuel curve shown in Fig. 3, it is found that a main-jet setting of 22 and a compensator setting of 21 will most nearly approach this ideal curve. Table 1 gives the total fuel-consumption and the fuel supplied through the main and compensator jets.

Road tests are not included in the scope of this paper,

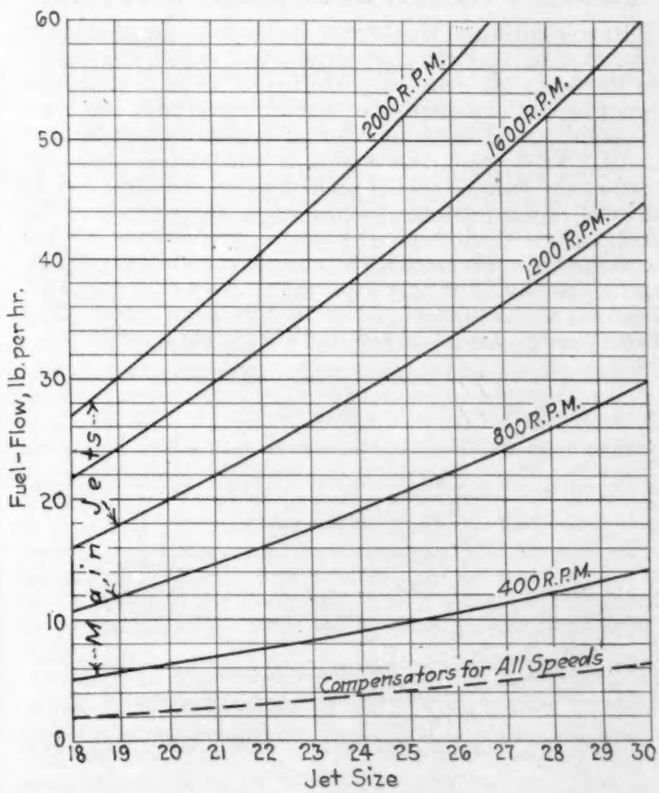


FIG. 4—CALIBRATION CURVES OF CARBURETER MAIN AND COMPENSATOR JETS

The Rate of Fuel-Flow through the Compensator Jet Is Not Affected by the Engine-Speed, Whereas That through the Main Jet Is Greatly Affected. Jets Both Much Smaller and Much Larger than the Size Required for the Best Engine Performance Must Be Used To Ascertain the Correct Size. Comparison of the Calibration Curves with the Total-Fuel-Consumption Curve in Fig. 3 Shows That a Main-Jet Setting of 22 and a Compensator-Jet Setting of 21 Will Most Nearly Approach the Ideal Consumption-Curve

TABLE 1—FUEL-FLOW THROUGH CARBURETER MAIN AND COMPENSATOR JETS AND TOTAL FLOW

Engine-Speed, R.P.M.	Maximum Power, B.Hp.	Fuel-Flow, Lb. per Hr. Main Jet, Size 24	Compensator Jet, Size 21	Total
400	15.0	9.0	2.5	11.5
800	32.0	19.0	2.5	21.5
1,200	48.0	28.5	2.5	31.0
1,600	59.0	38.5	2.5	41.0
2,000	60.0	48.0	2.5	50.5

but it may not be out of place to point out the usefulness of the jet-calibration chart in making such tests. Frequently it is found that a slight variation from the dynamometer setting of the carbureter will seem to give a better road performance. If a change from the dynamometer setting is thought advisable, it is well to consult the jet-calibration chart to see if the new combination will greatly affect the quantity of fuel supplied to the engine. If it will result in a large change in total fuel-consumption, it is best to consult the curves in Fig. 2 to determine how much the engine-power will be affected and on what part of the mixture-range curve the engine will operate. It is always possible that, in a road test, the road does not demand the maximum power or maximum speed of the engine. In that case the temptation to cut down the fuel to increase economy is great, but that means, in all probability, that the power will also be reduced and, while the power developed will be sufficient for that particular stretch of road, it may be necessary to have the extra power under other conditions.

Carbureter Performance at Partial Engine-Load

Having adjusted the jets of the several carbureters to be tested so that the carbureters will enable the engine to duplicate the selected performance closely, it will be necessary to compare the performance with one carbureter to that with another at less than full-throttle loads. To do this, the engine is run at less than full load at the various speeds. The maximum torque can be divided into a number of equal parts, say eight, and the fuel measured through the entire speed-range of the engine, while the torque is kept at one-fourth, three-eights, one-half and three-fourths of its maximum. Fig. 5 shows the results of a test of this description. The results in the top solid-line curve were obtained by running the engine at 400, 800, 1200, 1600, and 2000 r.p.m. with the throttle adjusted at each speed so that the torque remained constant, namely 35.0 lb-ft. Fuel measurements were made at each point. Then the run was repeated, keeping the torque at 52.5 lb-ft.; another was made at 70.0 lb-ft. and still another at 105.0 lb-ft. These loads represent one-fourth, three-eighths, one-half and three-fourths of maximum torque. The heavy dotted-line, the third curve from the bottom, represents the fuel consumption while the engine was running under full load at these same speeds. Naturally, during this last test, the torque developed at the various speeds was not the same but was the highest possible for each speed. The light dotted-lines represent the performance with another carbureter. It will be seen that these latter curves are, in the two lighter-loads, considerably above the heavy ones. In the case of the heavier loads, the curves for the two carbureters cross, the dotted ones showing a higher fuel-consumption at the lower speeds,

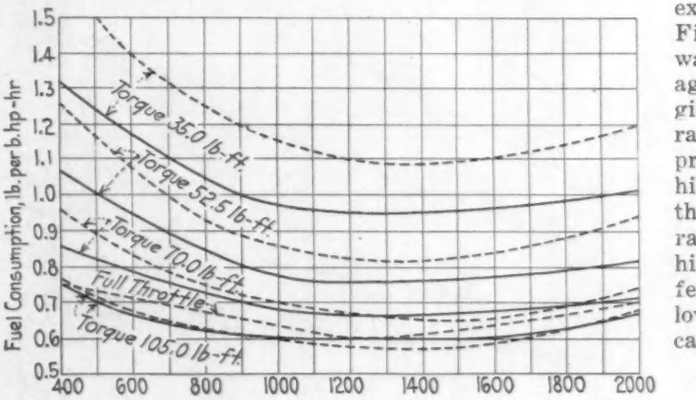


FIG. 5—FUEL ECONOMY AT CONSTANT TORQUE AND PART-THROTTLE OPENING

The Torque Loads Represent Respectively One-Quarter, Three-Eighths, One-Half and Three-Quarters of the Maximum Torque. The Full-Throttle Dotted Line near the Bottom Represents Fuel Consumption with the Engine Running under Full Load. The Light Dotted-Lines Indicate the Performance with a Different Carbureter and Show a Considerably Higher Consumption at the Lighter Loads. In the Case of the Heavier Loads They Show Higher Consumption at Both Low and Maximum Engine-Speeds and Slightly Less Consumption in the Middle Speed-Range

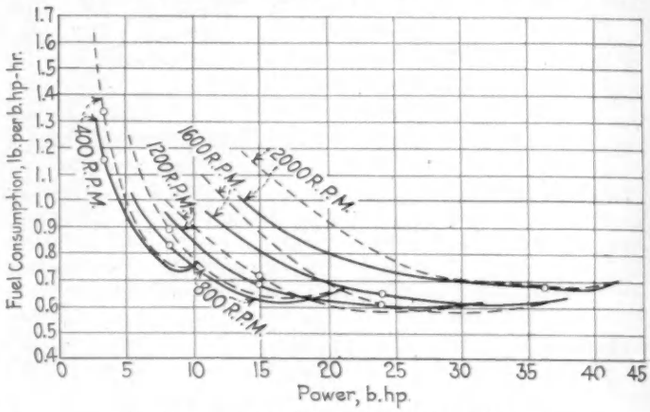


FIG. 6—FUEL ECONOMY AT CONSTANT SPEEDS

Data for the Curves in Fig. 5 Are Here Replotted as Specific Fuel-Consumption against Brake Horsepower and the Curves Give a Picture of the Engine Performance over Its Entire Range. Circles Denote the Power Required To Propel the Vehicle in Which the Engine Is To Be Used in High Gear on a Level Road at a Speed Equivalent to the Engine-Speed. Performance with Two Different Carbureters Is Shown

somewhat lower consumption in the middle range and slightly higher at 2000 r.p.m.

It is somewhat difficult, from the series of curves in this chart, to form a correct picture of what might be expected of these two carbureters in actual operation. Fig. 6 shows these same curves re-plotted in a different way, a curve of specific fuel-consumption being plotted against brake-horsepower for each speed. This graph gives a picture of performance over the entire engine-range. The circles denote the engine-power required to propel the vehicle in which the engine is to be used in high gear on a level road at a road speed equivalent to the engine-speed, taking into account, of course, gear-ratio, tire size, vehicle weight, and such details. Average high-gear road-economy probably would not be very different for these two carbureters. Fuel economy in the lower gears should be in favor of the carbureter indicated by the heavy lines.

How Acceleration and Idling Tests Are Made

To determine the accelerating ability of an engine as affected by a carbureter, it is necessary to operate the engine against a load similar to that imposed by the vehicle and road in actual use. The dynamometer loading can, of course, be regulated to approximate the road and wind resistance. The inertia force to be overcome due to the mass of the vehicle must be replaced by a flywheel of suitable proportions, attached to the dyna-

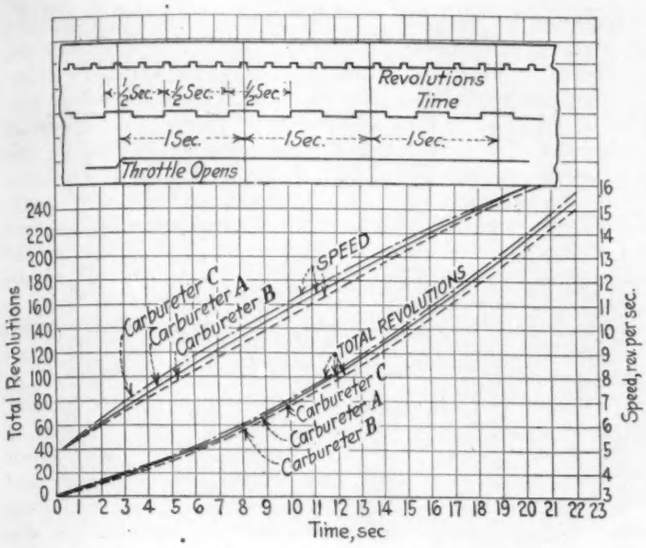


FIG. 7—ACCELERATION CHARACTERISTICS WITH VARIOUS CARBURETERS

A Section of Tape from a Recording Chronograph Is Shown at the Top and the Acceleration Curves Below Are Plotted from This Record. Each Notch in the Top Line Represents One Revolution of the Dynamometer Shaft, Each Notch in the Second Line Represents ½ Sec. of Time, and the Third Line Shows When the Throttle Was Opened. Results Given in the Lower Curves Are Obtained by Plotting the Number of Notches in the First Line Continuously against the Time and Show Which of Two Cars Would Be Ahead at Any Time. The Speed Curves Are Obtained by Plotting the Number of Revolutions Against the ½-Sec. Points

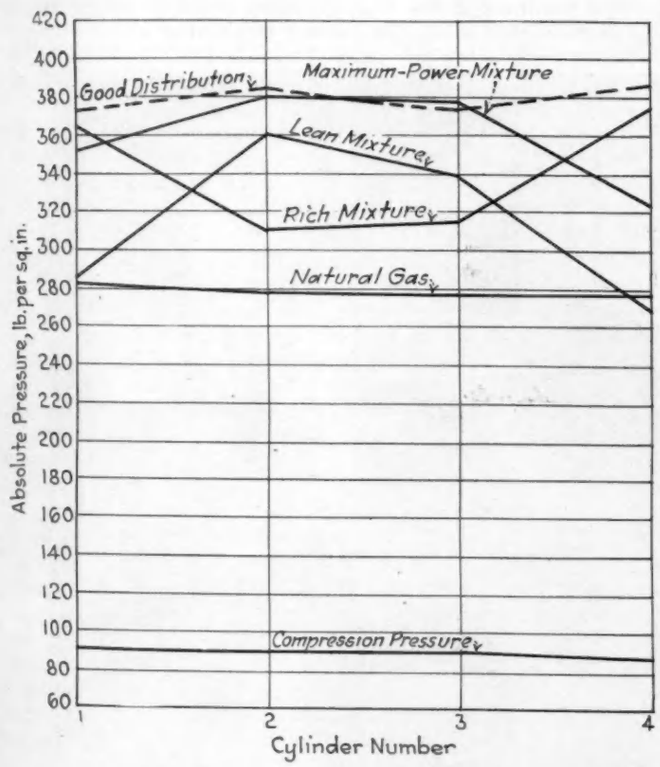


FIG. 8—CHARGE DISTRIBUTION SHOWN BY MAXIMUM EXPLOSION-PRESSURE

The Lowest Line Indicates Compression Pressure in the Four Cylinders and Is a Measurement of the Air Distribution, Which Is Practically Uniform. The Next Curve Above Shows the Explosion Pressure with Natural-Gas Fuel Used as a Check and Indicates That Distribution Is Practically Perfect. Curves in the Upper Group Were Taken with the Engine Operating on Gasoline. With a Lean Mixture, Cylinders 1 and 4 Showed Low Pressure and the Middle Cylinders High Pressure, Whereas with a Rich Mixture the Results Were Reversed. The Curve for Maximum-Power Mixture Shows the Pressure Distribution with the Carbureter Set for Maximum Engine-Power Developed by All Four Cylinders. The Dotted Line at the Top Was Taken on an Engine That Had Very Good Charge Distribution

ometer shaft. Then it is necessary to employ suitable equipment for measuring the time that elapses between successive revolutions. This can be done with a stop-watch and tachometer, or with a chronometric tachometer. A much better way is to use a recording chronograph. A section of tape from such a chronograph record and the curves plotted therefrom are shown in Fig. 7. On the tape are three records made by three electrically operated pens. Each notch in the top line represents one revolution of the dynamometer shaft. Each notch in the second record represents ½ sec. of time. The third line on the tape shows when the throttle was opened. The throttle opening determines the beginning of the run. From this point distances equal to intervals of 1 sec. each, as determined by the time pen, are marked off on the revolution line. Revolutions may be estimated to the tenth.

By plotting the number of notches in the first line continuously against the time, the results given in the

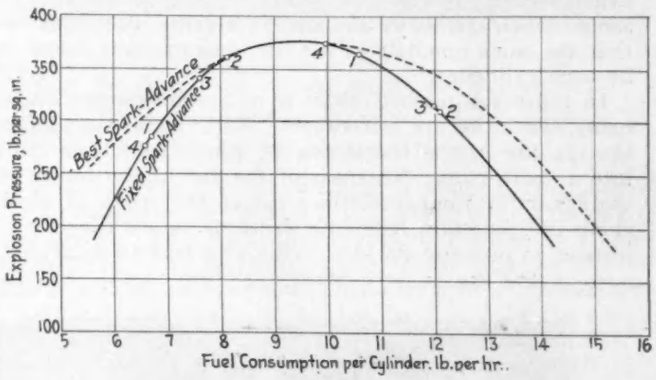


FIG. 9—EXPLOSION PRESSURE IN A SINGLE CYLINDER

These Curves Show the Effect on Maximum Pressure of Variation of the Mixture Ratio with Fixed and Varied Spark-Advance. Power Loss Is Incurred by the Use of Too Lean and of Too Rich a Mixture and also by Improper Spark-Advance. Numbers on the Solid-Line Curve Indicate the Pressures in the Different Cylinders, as Given in Fig. 8, Those on the Left Slope Being for the Lean Mixture and Those on the Right Slope for the Rich Mixture

lower curves on the chart are obtained, that is, distance against time. This would show which of two cars, for example, would be ahead of the other. The average speed during each second is equal to the number of revolutions that occurred during that second and is plotted on the half-second point. This gives the higher group of curves labeled "Speed." From the second curve could be drawn an acceleration curve expressing acceleration in revolutions per second per second, by plotting the difference in speed of two successive seconds, but unless it is required for some particular purpose, this curve can usually be omitted. If it is necessary to have this information, the experiment must be conducted with extreme care and the averaging should be done over smaller time-intervals than 1 sec. or the results will seem to be very erratic.

It is well, when making a test of this description, to adjust the dynamometer loading and carbureter throttle-position so as to keep the load equal to the power necessary to propel the vehicle at the engine-speed to which acceleration is to be measured. Having adjusted the load, the throttle is closed and the engine run at a low speed for a few seconds and then the throttle is opened. The time and revolutions shown on the chronograph tape previous to the throttle opening give the initial speed of the engine.

Idling tests can be made in connection with the acceleration tests after the idling jet has been adjusted so

that the engine runs at very low speeds when disconnected from the dynamometer. If loading occurs, that is, if fuel accumulated in the manifold, the acceleration will be bad for the first few seconds.

Study of Charge Distribution

Distribution of the fuel-air charge to the various cylinders of a multiple-cylinder engine is so much discussed at present and so important that a suggested method for studying this problem may be in order. Various methods for its study while the engine is in operation are in use, such as analysis of the exhaust-gas and measurement of an average temperature in the several cylinders. The first method, of course, reveals the products of combustion in the various cylinders, provided a true sample of the exhaust-gas from each cylinder is obtained. The collecting of such a sample is very difficult, especially in an engine in which two cylinders have a combined exhaust-port. It is also questionable whether the fact that exhaust-gas from several different cylinders has the same carbon monoxide and carbon dioxide content shows that the same quantity of air and gasoline was taken in by each cylinder.

In the other method, that of measuring temperature, many difficulties are introduced. Many factors can affect the reading of the thermocouple, which usually is built into a spark-plug. Nearness of the end of the couple to the spark terminal sometimes causes the spark to creep along the porcelain from the electrode to the couple end instead of jumping its gap. This produces an occasional miss in the engine or a weak explosion that is not detectable by listening to the engine, and this in turn causes the temperature in that cylinder to fall very materially. This short-circuiting was discovered by interchanging the couples in an engine that showed a particularly bad temperature-distribution. As a certain thermocouple was changed from cylinder to cylinder, the low-temperature phenomenon followed it. After fixing the one thermocouple, another developed the same fault, hence this method of study was abandoned and a search for another was made. Creeping of the spark from the electrode to the end of the thermocouple can practically be eliminated if an auxiliary spark-gap is put in series with the plug. This raises another difficulty, however; the presence of an auxiliary gap seems to affect the temperature of the gas surrounding the plug.

It was decided, after considerable experimentation, that a measurement of maximum explosion-pressure in the various cylinders would be the easiest and safest method to use. The pressure method can easily be used to check-up the air distribution; that is, by measuring the compression pressure, the fuel distribution can also be obtained by measuring the maximum explosion-pressure, and a further check can be made by using illuminating or natural gas. A balanced-diaphragm indicator, such as was developed by the Bureau of Standards, was used for this purpose. Each cylinder was fitted with a pressure element and the upper space of each element was fed from the same pressure-line. The electric connections of each were run through a four-point switch, and readings in the four cylinders could be taken readily by switching from one contact to another.

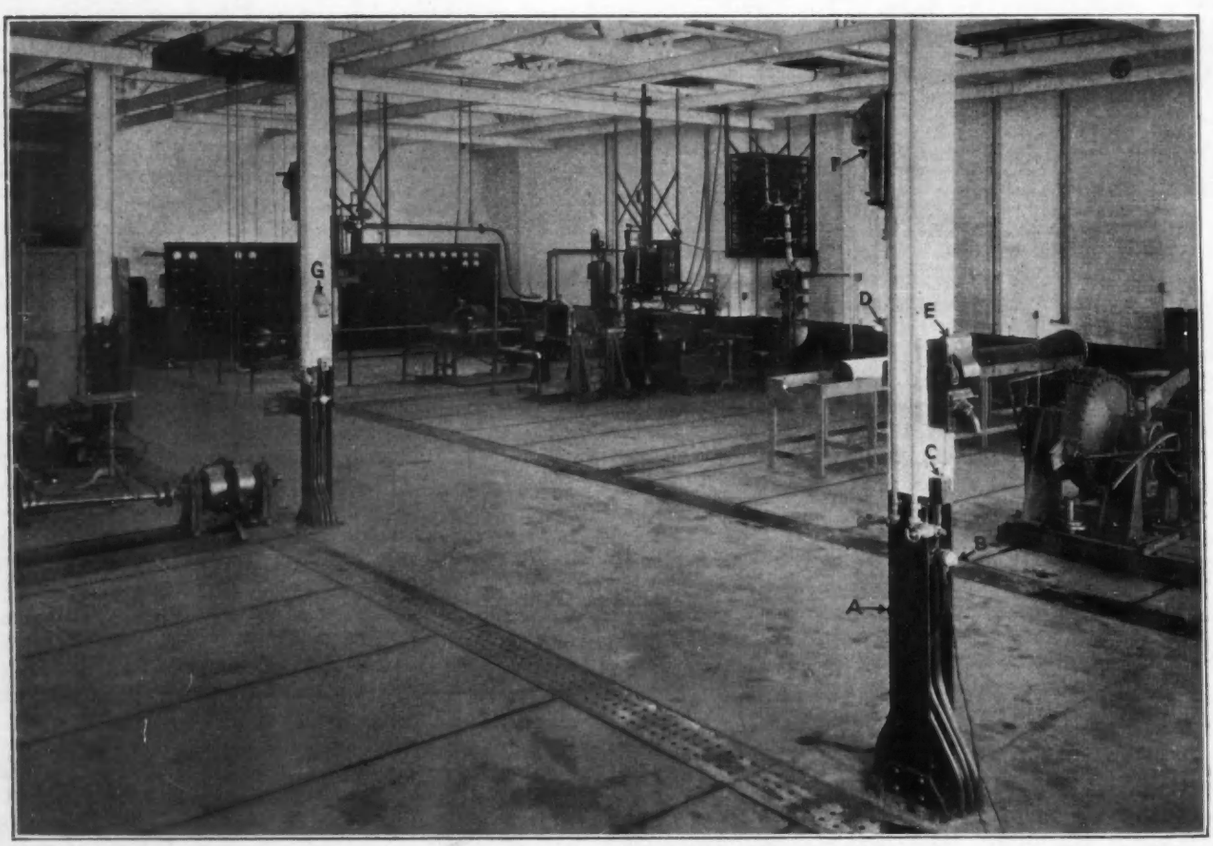


Fig. 10—Specially Designed Laboratory and Its Equipment

The Room Is Spacious and Well Lighted by North Windows in the Saw-Tooth Roof. T-Slot Rails in the Floor, Spaced 4 Ft. Apart, Are for Bolting-Down the Dynamometer and Engine-Support Bed-Plates. Floor Drains Are Located at 20-Ft. Intervals. A 10-Ft. Overhead Transfer-Crane Travels on Monorails. Each Column Carries Outlets for Electric Current as Follows: *A*, 120-Volt Alternating; *B*, 120-Volt Direct, Polarized; *C*, Variable-Voltage Direct, Polarized; *D*, Three-Phase 220-Volt Alternating; *E*, Heavy-Current Variable-Voltage Direct; *F*, Three-Phase 440-Volt Alternating; and *G*, Heavy-Current 120-Volt Direct

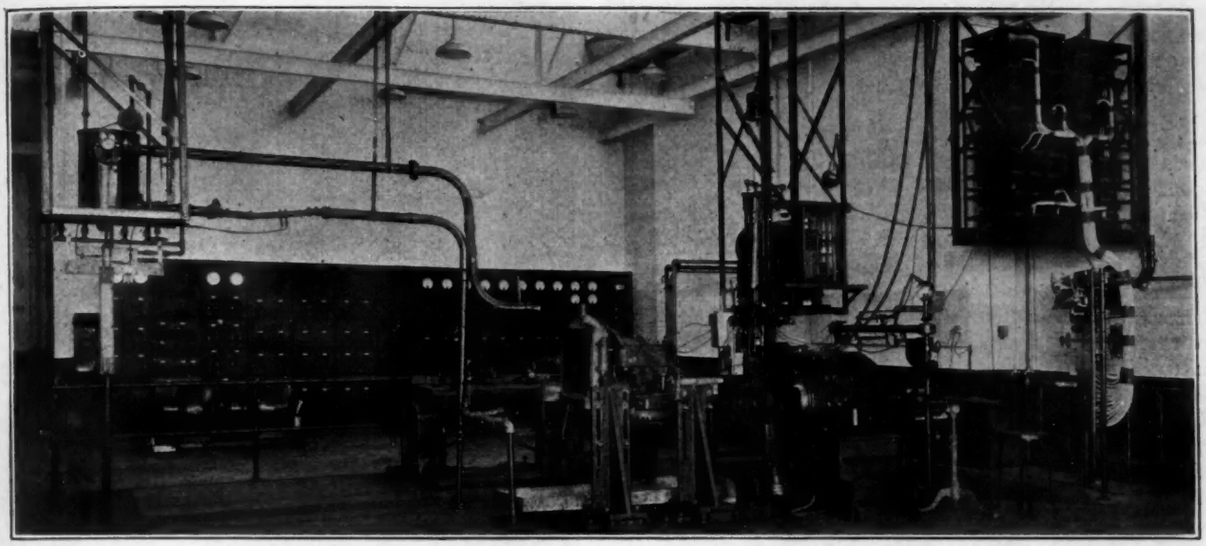


FIG. 11—MAIN SWITCHBOARD AND DYNAMOMETER AND ENGINE SET-UP
Two Direct-Current Motor-Generator Sets Supply the Constant and Variable-Voltage Current Which the Switchboard Distributes for the Laboratory together with Alternating Current for the Entire Engineering Building. Each Dynamometer Is Equipped with Its Own Cooling-Water System, as Seen at the Left, and with a Fuel-Measuring System, Seen Above the Dynamometer

RESULTS OF MAXIMUM EXPLOSION-PRESSURE TESTS

In making tests of the maximum explosion-pressure for studying distribution, the engine should first be run with as lean a mixture as the engine will operate on and fire all of the cylinders. The cylinders receiving the leanest part of the mixture will then show a very low pressure. Next the engine should be operated, developing preferably the same power, on a rich mixture and the cylinders receiving the richest part of the mixture will show the lower pressure. Fig. 8 shows the results of such a test. The lowest line is a measure of the compression-pressure in the various cylinders and is, therefore, a measurement of the air distribution. Precaution was taken to have the compression space in the several cylinders absolutely equal in volume. The next curve above shows the maximum pressure in the cylinders when the engine was operated under its own power with natural gas as a fuel. It will be noted that the distribution is practically perfect.

The curves in the next group were taken with the engine operating on gasoline. The lean-mixture curve shows high pressure in the middle two cylinders and low pressure in the two end cylinders. The maximum difference in pressure between the middle and end cylinders is about 80 lb. per sq. in. The rich-mixture curve shows low pressure in the middle two cylinders and high pressure in the end cylinders, the maximum pressure-difference being about 65 lb. per sq. in. In the former case the mixture in the two end cylinders was too lean to develop a high pressure, and in the latter case the middle ones could not develop a high pressure because the mixture was too rich.

The third curve of this group shows the pressure distribution with the mixture set for maximum engine-power developed by all four cylinders. Had this curve alone been taken, it would not have been possible to determine definitely whether the end cylinders had a low pressure due to receiving too little gasoline or too much.

The dotted curve at the top in Fig. 8 was taken on an engine that had very good distribution. The graphs of Fig. 7 show the effect of bad distribution but are not quantitative. To obtain information for a quantitative analysis it was decided to make a study of maximum explosion-pressure variation with variation of the mixture-ratio. This naturally had to be done on a single cylinder, but, to be useful for studying distribution on the particular engine under observation, it was necessary that this single-cylinder engine have exactly the same combustion-space, both as to shape and volume, and the same valve and intake system, as the four-cylinder engine. It was, therefore, decided to use one of the four cylinders of the engine. The two middle cylinders were made inoperative by taking out the inlet tappets, and a carbureter was fitted to each of the intake ports of the remaining two cylinders. The engine was thus a two-cylinder engine, with two carbureters, the two end cylinders being operative and the two middle cylinders inoperative. The studies were made on cylinder No. 1, and for this reason a half of a manifold was made and the carbureter was connected with the intake port of the cylinder by this manifold. As operative cylinder No. 4 was not used in the investigation except for assisting in the running of the engine, its intake port was connected with the carbureter by a straight pipe.

The results of this study are given in Fig. 9, in which maximum pressure is plotted against fuel consumed in pounds per hour for the single cylinder. The solid-line curve was obtained by determining the best spark-setting for the charge that produced maximum explosion-pressure and maintaining that setting for readings at different mixture-ratios. The dotted-line curve was produced by adjusting the spark to the maximum explosion-pressure for each mixture-ratio, or rate of fuel consumption. It is evident from these two curves that the loss due to bad distribution is twofold, that (*a*) incurred by too weak or too rich a mixture and (*b*) brought about by improper spark-advance. An engine that has uneven mixture-distribution should have uneven spark-advance; that is, each cylinder should have a different advance, which is impracticable.

The numbers on the solid curve show the pressures developed in the various cylinders during the test, the results of which were given in Fig. 8. The numbers on the left slope of the curve in Fig. 9 are those for the

lean setting, while those on the right slope are for the rich setting. Fig. 9 explains why the results in Fig. 8 were obtained, and from it the amount of fuel delivered to each cylinder can be calculated.

Laboratory Layout and Equipment

It is necessary to have suitable equipment for the conduct of any investigation. By equipment is meant not only instruments and apparatus but a building as well. It is not always possible, in laying out a laboratory, to have the privilege of designing the building for it. This was possible, however, in the particular case which shall be outlined here. A careful study of the work that probably will have to be done in the laboratory is naturally a good way to start.

After this study has been made, it is well to realize that undoubtedly some problems that were not included in the survey will have to be undertaken and for this reason all equipment should be so designed that changes can be made as easily, quickly and cheaply as possible. The following facts, however, are known with certainty:

(1) It will be necessary to bolt equipment to the floor
(2) It will be necessary to drain water
(3) Sufficient working space must be available
(4) The entire space must be well lighted
(5) The room should have a high ceiling
(6) The room should have good crane-transportation

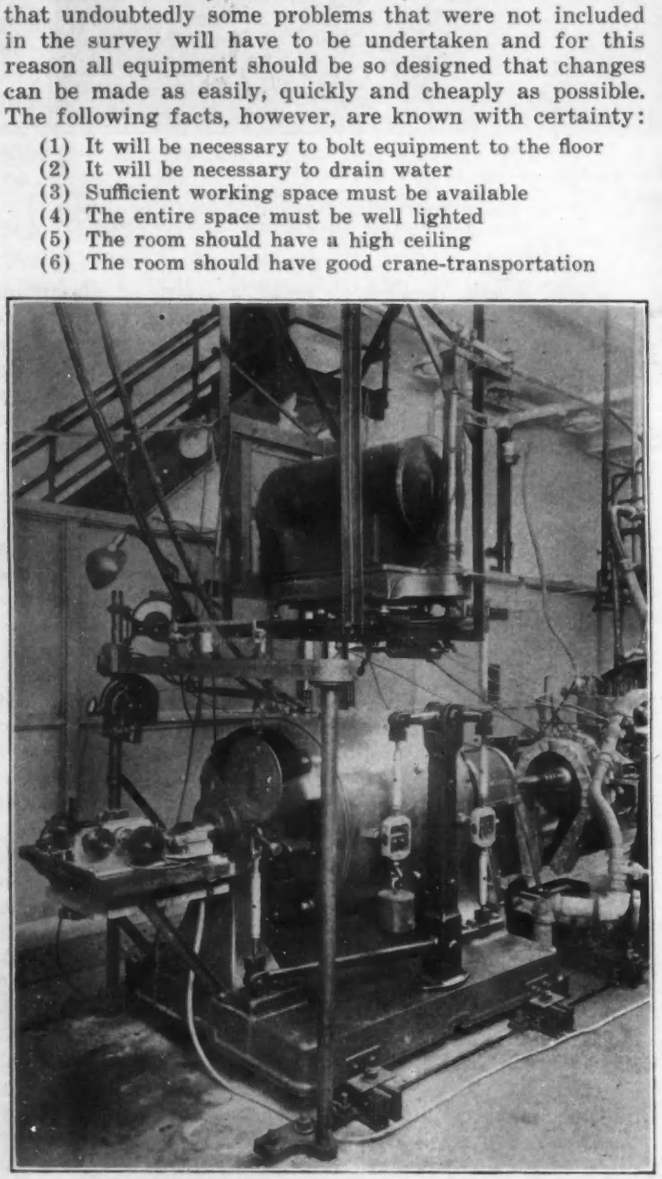


Fig. 12—Dynamometer, with Weighing, Measuring and Counting Accessories

Levers on the Weighing System Have the Proper Multiplication To Make the Torque Read at 63-In. Arm for Easy Horsepower Calculation. Graduations in 0.10 Lb. on the Scale Beam Are Far Enough Apart To Permit of Estimating Loads within 0.02 Lb., and the Whole System Is so Sensitive That 0.25 Lb. Put on the Field Frame Can Be Weighed Easily on the Scale. Other Instruments Carried on the Dynamometer Are a Rotating Spark-Gap with Protractor, Two Revolution Counters and a Timer for the Balanced-Diaphragm Indicator

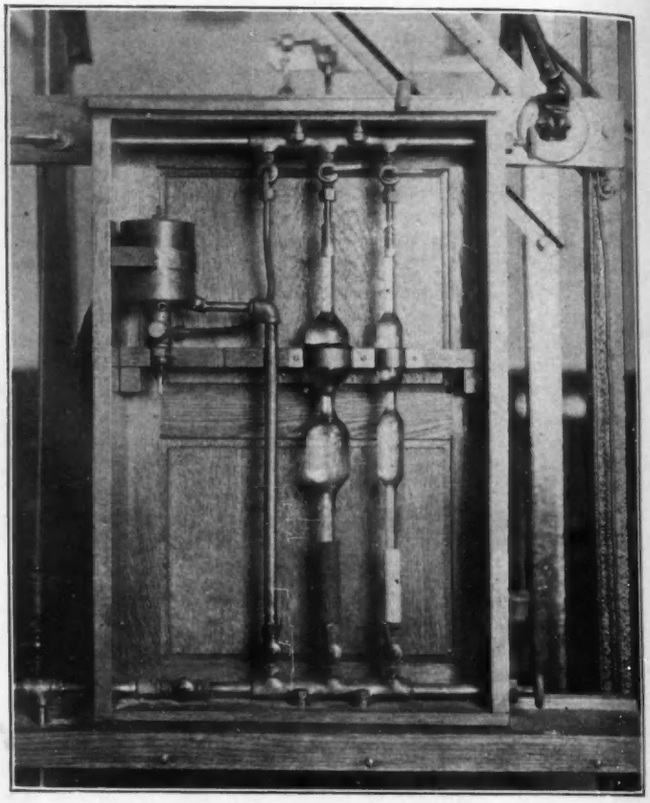


Fig. 13—Apparatus for Measuring Fuel Consumption Volumetrically

This Consists of Two Glass Pipettes, a Float-Chamber, a Thermometer, and Necessary Cocks for Controlling the Fuel-Flow. To Make a Measurement, the Main Cock under the Float-Chamber and a Cock below One of the Pipettes Are Opened until Fuel Fills the Pipette to the Level of the Float-Chamber. Then the Main Cock Is Closed and When the Fuel Has Dropped to the Upper Gage-Mark on the Neck of the Pipette, a Stop-Watch Is Started. When the Fuel Drops to the Lower Gage-Mark at the Middle of the Pipette, the Watch Is Stopped and the Main Cock Is Opened Again so That the Engine Will Continue To Run. One Pipette Is of 0.20 and the Other of 0.50-Gal. Capacity

(7) Provision will have to be made for conducting away exhaust-gas

The laboratory, of which a general view is presented in Fig. 10, is very spacious and is lighted with a saw-tooth roof, the windows of which face north. The floor is provided with T-slot rails, spaced on 4-ft. centers. Floor drains 12 in. wide and 6 in. deep and running parallel to the T-slot rails are located at 20-ft. intervals and connected with two headers of similar dimensions that extend the entire length of the laboratory on either side of a 10-ft. corridor. The overhead crane system consists of monorails, all of which connect with a small 10-ft. transfer-crane. The roof structure is such that additional monorails can be installed without having to do any drilling in the beams or an existing rail can be moved easily. The dynamometers are bolted to the floor rails and each pair of engine supports has a small bed-plate. This arrangement gives a very good adjustment and set-ups are not limited by the length of a bed-plate.

At the far end is the powerplant, which consists of a switchboard that distributes the current not only for the laboratory but for the entire engineering building, two direct-current motor-generator sets and a small vacuum-pump. The air-compressor is in the basement.

The exhaust system consists of a length of 6-in. pipe down each side of the laboratory, suspended from the basement ceiling. At every 20 ft., which is a probable dynamometer-location, a T carries a connection to the floor above. The two lines on either side of the labora-

tory are connected together and enter the suction side of a blower, which discharges into a stack consisting of 10-in. piping that projects through the roof. A water separator is installed in the line before it reaches the blower. It is important that a water separator of some description be installed because a greater quantity, by weight, of water is in the exhaust-gas than the amount of fuel burned, and, since the temperature of this long line of exhaust-piping will drop below the boiling-point of water, the condensation of water vapor would cause considerable trouble. The engines are connected to this exhaust-line through suitable piping and a gate-valve. The gate-valve is used to adjust the back-pressure for each speed and load to coincide with that which the engine must operate against when installed in a vehicle and running under similar conditions.

A closer view of a dynamometer and engine set-up, as well as of the main switchboard, is presented in Fig. 11, in which the method of supporting the engine is plainly visible. While this particular set-up has a radiator connected to the engine, the radiator can be removed easily and the engine attached to the laboratory cooling-water system. Each dynamometer is equipped with its own cooling-water system, which, as shown at the upper left, consists of a small tank, piping, venturi meter, and thermostat. The fuel-measuring system above the dynamometer is also plainly visible. Either a scale or the volumetric equipment can be used. The absorption grids are above the switchboard.

Electric-Current Powerplant and Distribution

It is well to discuss the powerplant a little more in detail. Two sources of direct current are employed so that the field circuits of the dynamometers may be excited separately from the armature circuits. The field exciter is a 20-kw. machine and its voltage is always kept at 120. The generator that furnishes armature current is a 90-kw. machine and its voltage can be varied from 12 to more than 250. This means that the dynamometer can be used for measuring input at very low speeds by changing the armature voltage and without using any series or parallel resistances in the circuit. While the equipment for doing this is expensive, it is convenient and makes possible the performing of experiments with the dynamometer that could not be done with any other system.

The first three sections on the left of the large switchboard are for direct-current distribution. Each dynamometer has one field switch on these panels and one armature switch. The rest of the panels on the switchboard are for distributing alternating current. All of the oil switches are in the basement, and merely the operating levers are on the board. The main switch, carrying 11,000 volts, can be operated from the switchboard but is situated at the main station in the factory. The vacuum-pump can maintain a vacuum of more than 20 in. of mercury and is used to supply vacuum for general laboratory-purposes. It cuts in and out automatically.

Numerous outlets for current are situated at different places in the laboratory. Along the walls there is an outlet every 20 ft., and each column carries all the various outlets. The lower one, 30 in. from the floor as indicated in Fig. 10 at *A*, is the 120-volt alternating lighting-current outlet. The one next above at *B* on the right is the 120-volt direct-current outlet. This is a polarized outlet and the vertical pole is positive. Outlet C is for the variable direct-current voltage, also polarized, and the lower pole is positive. Outlet *D*, 6 ft. from the floor, is for three-phase 220-volt alternating current. On the opposite side of the column a 250-volt direct-current supply for heavy-duty work is available at *E*. Outlet *F* is a large box for 440-volt three-phase alternating current. There are only two of these latter outlets in the laboratory and each is protected by an interlocking switch. The outlet *G* is a heavy-current outlet for 120-volt direct current. The fixtures for these various outlets are all different so that the likelihood of attaching a piece of apparatus to a wrong current-source is remote. Besides the electrical outlets, hot and cold water, high-pressure and low-pressure air, gas, and vacuum outlets are situated in convenient places. A

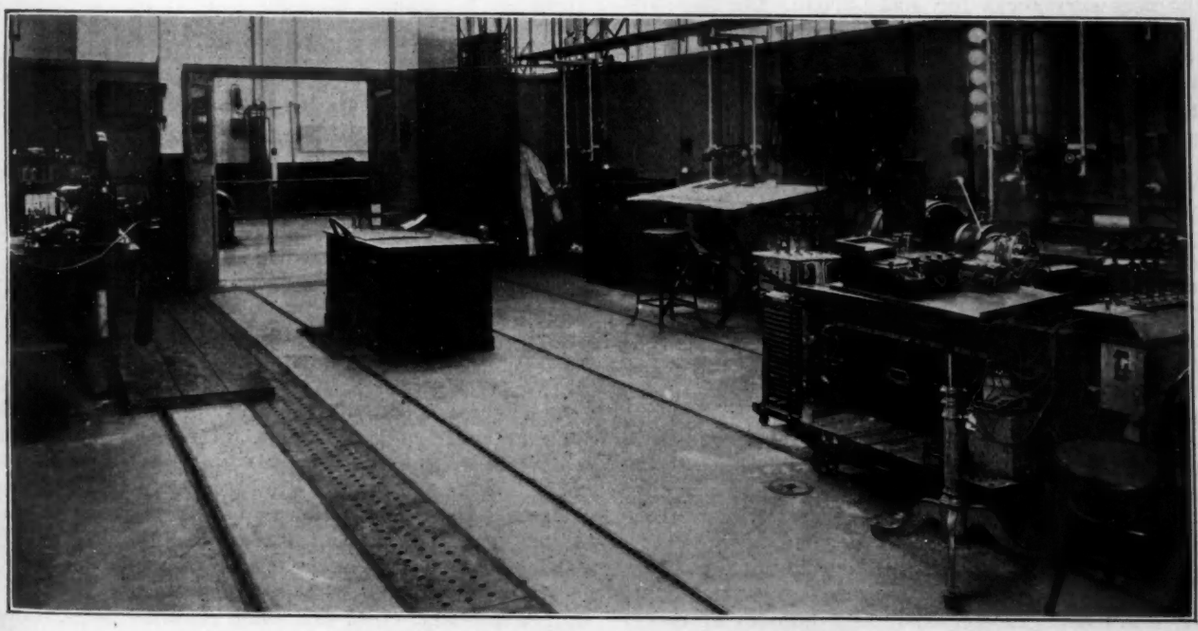


Fig. 14—Segregated Laboratory for Electrical and Apparatus-Calibrating Work
At the Right Is an Electric Generator Test-Bench and on the Extreme Left Is a Laboratory Table for Calibrating Thermometers, Gages, Tachometers, and Other Instruments. A Large Piece of Machinery Can Be Moved into This Room with a Crane, if Desired

color scheme is used to distinguish the different pipes, green for hot water, blue for cold water, orange for 15-lb. air-pressure, gray for 100-lb. air-pressure, aluminum for gas, and brown for vacuum.

Test Measuring-Apparatus and Its Operation

The closer view of a dynamometer in Fig. 12 shows the weighing system and its accessory apparatus for counting revolutions and the like. The weighing system consists of a set of levers of the proper multiplication to make the torque read at a 63-in. arm, so that horsepower calculation is easy. The upper beam is for reversing the pull on the scales; that is, it operates when the dynamometer is used for measuring input, as when measuring the friction horsepower of engines. All of the levers are mounted on ball-bearings instead of knife edges, and this has worked out very well. The scale beam is a small beam mounted on agate and graduated in 0.10 lb., with the graduations far enough apart to estimate to 0.02 lb. if such accuracy is necessary. The whole system is so sensitive that 0.25 lb. put on the field frame can be weighed easily on the scale. The sensitivity depends a great deal on the flexibility of the leads connecting the dynamometer to the source of power supply. The only material that has so far been found to be satisfactory is extra-flexible brush-holder cable, and even with this it is necessary to use a considerable length; the cables for the installation shown are more than 12 ft. long.

Fig. 12 also shows the instrument for measuring the spark-advance, which is, of course, only a rotating spark-gap and a protractor. The revolution counters and the timer for the balanced-diaphragm indicator are also visible. Two revolution counters are so arranged that when the push-button is pressed, one is engaged and the other disengaged. The exhaust connection, including the gate-valve for controlling the back-pressure, can also be seen.

Apparatus for determining the fuel consumption volumetrically is shown in Fig. 13. This apparatus consists of two glass pipettes, a float-chamber, a thermometer, and the necessary cocks for manipulating the fuel-flow. The pipettes are of two sizes, namely, 0.20 and 0.50-gal. capacity. Each has a mark on the upper neck to indicate when it is full to capacity and one on the middle neck marking half capacity. To use the instrument, the main cock underneath the float-chamber and the one under the pipette that it is desired to use are turned on. With this setting, fuel will flow to the engine and the excess fuel will rise in the pipette until the level of the float is reached, which is somewhat above the upper gage-mark. To make a fuel measurement, it is necessary merely to turn off the main cock under the float-chamber, start a stop-watch when the upper gage-mark is passed and stop it when the lower mark is passed. Then open the main cock again and the engine will continue to run and the pipette will refill itself. A temperature reading should be taken.

To convert this fuel measurement into pounds, a standard ½-gal. measure is filled with gasoline at the temperature taken and weighed on a balance. For longer tests, weighing the gasoline on a scale is more convenient and probably more accurate than a volumetric determination. When it is necessary to make a long test and weigh the gasoline, an automatic electric counting-device is used. This consists of a number of relays so arranged that when the scale beam falls a counter operated electrically by a seconds clock is started and at the same time the revolution counter on the dynamometer shaft is also started. Then a small dial-switch is moved to its second contact-point, and every time the beam falls after a predetermined quantity of fuel has been consumed a small bell rings. The seconds counter may then be read and the revolution counter changed. For stopping the test, the small rotary-switch is moved to its third contact-point and the next time the beam falls the entire apparatus, that is, both the seconds counter and the revolution counter, is stopped. A temporary form of this device has been in use for some time and has proved so satisfactory that it is being reconstructed into a more permanent piece of equipment.

Small Laboratory-Work Is Segregated

It is advisable to separate the smaller laboratory work from the larger, and for this reason a small laboratory, as shown in Fig. 14, was installed for doing electrical work and for calibrating the apparatus. On the right is the electric generator test-bench and on the extreme left a laboratory table for calibrating thermometers, gages, tachometers, and the like. Any small laboratory work can be done in this room. It has exactly the same floor structure as the entire laboratory and a large piece of machinery can easily be moved in with the crane.

For special work, it is necessary to build special apparatus but such equipment should be as simple as it can be made.

Not much can be said regarding the technique of making observations except that the observer must learn to use all of his senses, not only that of sight. A classic example of how *not* to make observations is the method usually employed by the layman to compare a watch with a seconds-beating clock. He looks at the clock and then at his watch, then back at the clock and once more at the watch, and so on, increasing the speed until it seems as though he would dislocate his neck, yet he cannot look at both the clock and the watch at exactly the same time. If he would realize that nature blessed him with several other senses and, while looking at the clock, would count a few seconds with it to get the rhythm, then, by comparing the seconds on the clock, which he counts, with the seconds on his watch which he sees, an absolutely accurate comparison could be made easily and quickly.

THE DISCUSSION

A Member:—I wonder how Mr. Jehle ever induced his company to appropriate the necessary money to build and equip the laboratory he described. Usually the executives of a company look around the plant and, if they have a little space that they think cannot be used for some other purpose, they will partition that off and put in an experimental laboratory. I was impressed especially by Mr. Jehle's exposition of the thoroughness with which his company attacks its various problems. Although much has been published in the engineering journals about experimental work, I believe we shall see far greater developments in this line of work in the next 5 or 10 years.

We have reached the stage in automotive work where we have a thorough knowledge of steels and all the other materials of construction but we have much to learn about the finer problems that Mr. Jehle has discussed, such as charge distribution and the precise effects of the carbureter, magneto, air-cleaner, and all of the various accessories upon which the engine is so dependent.

Will Mr. Jehle tell what comparison he makes, for instance, on magnetos, and what method he follows in comparing the relative efficiency of different types of spark-plug? That has become a problem with the present tendency to go to higher engine-compression.

FERDINAND JEHLE:—I do not know of any real test to compare spark-plugs easily and quickly except to run them in the engine. I hope we may be able some day to find a method by which it can be done more quickly.

I have not found it necessary to test magnetos, so far as furnishing the spark with which to run the engine is concerned. Of course we make life tests of magnetos on the bench. Magneto manufacturers are now making so-called waterproof magnetos. These we test by spraying water on them with nasal sprays. Some of them resist this moisture test rather well, but it is a severe test, much more severe than pouring a bucket of water on them. An ordinary magneto that is not waterproof can be put out of operative condition in 20 min. by this simple test.

DANGER IN CORRECTION FOR TEMPERATURE

A. W. POPE, JR.:—What weight do you place on corrections for temperature and barometer?

MR. JEHLE:—We always correct for the barometer, even in the production testing of engines. The tester has a curve that every engine must meet as it goes through the line, and he is permitted to correct for barometric variation, because the power varies directly as the barometer varies, but he is not permitted to correct for temperature. When temperature is measured in the valve pocket the power seems to vary inversely as the absolute temperature. The Bureau of Standards, I think, recommends that the power be corrected as the square root of the absolute temperature. This, however, refers to room temperature.

The problem, as I see it, is simply this: If the temperature increases, the mass of the charge necessarily must decrease and therefore the power should go down with the mass, but as soon as the temperature goes up, more gasoline will be vaporized and there will be more refrigeration. If the range has not been very great, the temperature of the gas that goes into the engine is probably the same as it was before, hence ordinarily it is very dangerous to correct for temperature, and my experience has been that usually when it is done the correction is too generous by far.

ANTON F. BROTZ:—Have you had any experience with a single-jet carbureter without a compensating air-valve?

MR. JEHLE:—We use a carbureter that has a comsating jet. Our experimental results, which were shown as power plotted against mixture-ratio and showed total fuel consumption, were run with a single-jet carbureter. The main jet was blocked out and readjusted for every engine-speed, without any compensation whatever for the different performance of the jet due to speed change. I do not believe one would get a proper fuel quantity for different speeds without some compensating device.

A. R. CONSTANTINE[2]:—What methods have you found best in the investigation of cylinder-wall temperature for determining the effectiveness of the cooling system and whether there are hot-spots in the cylinders?

MR. JEHLE:—I have measured many piston-heads and piston-walls and think I should measure cylinder-wall temperatures in about the same way. I would pass a thermocouple through the water-jacket and hold it on the cylinder-wall with a screw in the particular place where I wanted it. All of these temperature measurements are very delicate to take. First, one must be sure that the thermocouple is always located at exactly the same place when comparisons are to be made. The temperature gradient through the wall probably is more or less steep, and if the thermocouple hole should be drilled in 1/32 in. farther one time than another the thermocouple would show a difference in temperature.

RELATIONSHIP OF COOLING-WATER TEMPERATURE

A MEMBER:—What relation is found between the water temperature and the power output, and also between the water temperature and the carbureter action?

MR. JEHLE:—Offhand I should say that no absolute relation could be given. Whatever relation existed in one engine probably would not exist in another.

F. M. YOUNG[3]:—When there were differences in maximum explosion-pressure in the cylinders did you bring your relations to the circulation of the water in the feeder in the rear of the engine? When one cylinder at the rear end or the front end was running hot, that might be attributed to distribution of considerably more fuel, or a heavier charge, from the manifold or it might be due to a difference in water temperature. Would you attack that from both angles?

MR. JEHLE:—I have not made a study of this.

MR. YOUNG:—Then you might move the manifold around a little or put in a restriction and would perhaps not gain the end desired if the layout was bad for foundry practice or something like that.

MR. JEHLE:—Probably most of the uneven water-temperatures are due to uneven distribution of the water. It is possible, of course, that an uneven distribution of the fuel charge might result in uneven water-temperature.

MR. YOUNG:—It is attributed to that many times.

W. F. KRENZKE:—Have you any data that would prove whether the apparent uniformity of explosion pressures in the charge-distribution study was due to uniform mixture or to a change in volumetric efficiency of the various cylinders as compared with the lean mixture?

MR. JEHLE:—Absolutely. If an engine is run with illuminating gas or natural gas and the test shows perfectly even distribution in the cylinders, the air distribution, or the volumetric efficiency must be uniform. Then if gasoline is used as fuel and one cylinder shows low pressure and another shows high pressure, that must be due to erratic distribution of the charge. The same determination could be made by temperature tests. My program called for measuring the distribution with temperature readings but we had so much trouble with the thermocouples in knowing what the temperature readings actually meant that the method was abandoned.

MR. BROTZ:—Why does a cold engine start quicker with a partially closed throttle than with an open-throttle?

MR. JEHLE:—If the throttle is closed the depression in the manifold is greater than if it is left open and the pressure in the cylinders is lower. With a lower pressure the liquid fuel vaporizes more readily at a given temperature and distribution might be better.

TESTS RUN ON A SYSTEMATIC BASIS

A MEMBER:—Is all of the laboratory equipment that has been illustrated used on all phases of your work, that is, on transmissions, axles, engines, clutches, and other parts?

MR. JEHLE:—Yes, it is so arranged that it can be moved about easily. Our crane capacity is about 3 tons, which is about the weight of a dynamometer, and we can take one up readily and move it. I once had the problem of testing a number of winches, which required taking

[2] Development engineer, Harley-Davidson Motor Co., Milwaukee.

[3] M.S.A.E.—Vice-president and general manager, Racine Radiator Co., Racine, Wis.

about 15 hp. from a shaft that turned about 15 r.p.m. For that purpose we used an Alden brake, which is very useful for heavy absorption at very low speeds. Two dynamometers can be moved together if it is desired to test a transmission for efficiency.

Naturally, we do not change every day to a different line of work. It is a good plan to so group one's work that it can be done as nearly as possible on a production basis. To illustrate, if a man should want an air-cleaner tested I should wait until we had collected a number of different samples of air-cleaner and then have the equipment set up for that work, and when it was ready we could push that series of tests through. That might take 1 or 6 months, but the equipment would be set up once for that test and we would finish with it. Then the equipment would be changed around for some other problem.

H. D. SEELINGER:—Do you give motorcoach and motor-truck engines any different characteristic tests, and can you suggest any different methods of testing the former?

MR. JEHLE:—The motorcoach engines are put through exactly the same tests as the truck engines.

MR. SEELINGER:—Are they run on natural gas?

MR. JEHLE:—No, they are all run with gasoline.

CANNOT DUPLICATE ROAD CONDITIONS IN LABORATORY

MR. CONSTANTINE:—Do you endeavor in the laboratory to duplicate troubles that may be caused by vibrations from road shocks transmitted through the static parts of the vehicle, such as housings and frames? Suppose that certain troubles with a new model are reported from the road which cannot be duplicated or are extremely difficult to duplicate in road work. Then when an improvement has been made, how can the percentage of improvement be determined?

MR. JEHLE:—Generally speaking, I am not much in favor of making tests under imitation conditions. Before one can make a set-up for tests to duplicate road conditions he must know exactly what those conditions are. The best way to make comparative tests is to make absolute tests and compare the results. My experience has been that when one tries to set-up something that will simulate all of the motions and vibrations caused by the average road he usually fails. If one knows exactly the conditions under which a failure of a mechanism occurs, or which of the various conditions has produced the failure, it is rather easy to investigate the piece of apparatus from that angle. But unless he knows exactly which of several road conditions, so-called, produced the failure, he cannot be sure of reproducing it in the test It is very difficult to duplicate road conditions and it is equally hard to make tests on the road under identical conditions because the conditions are uncontrollable. It usually is better to test a device under a large number of controllable conditions in a laboratory, after which it is as easy to select the conditions that will apply to a certain road as to try to make the test under what might be called road wiggles.

Discussion of Papers at the Annual Meeting

THE discussion following the presentation of two of the papers at the 1926 Annual Meeting of the Society held at Detroit is printed herewith. The authors were afforded an opportunity to submit written replies to points made in the discussion of their papers and the various discussers were provided with an edited transcript of their remarks for approval before publication.

For the convenience of the members a brief abstract of each paper precedes the discussion so that members who desire to gather some knowledge of the subjects covered without referring to the complete text as originally printed in the February issue of THE JOURNAL can do so with the minimum effort.

This completes the publication of the discussion of the papers presented at that meeting, the discussion following the presentation of four papers having been printed in the July issue and that of three other papers having been published in the September issue of THE JOURNAL.

SUPERCHARGING INTERNAL-COMBUSTION ENGINES

BY C. R. SHORT[1]

ABSTRACT

WITHOUT attempting a scientific discussion of supercharging, the paper presents historical data concerning engines in which the supercharging principle has been employed, such engines being those which utilize special means whereby the cylinder charge is increased beyond the normal charge obtained by filling the cylinder at atmospheric pressure. The object of supercharging is to obtain a greater output of horsepower, due to the greater quantity of fuel mixture consumed and the resulting additional heat-units set free during combustion.

The piston-pump, the vane-pump, Roots blower, and the turbo-compressor are the four types of pump used to supply the required quantity of gas-and-air mixture, a pump of some suitable design being an essential feature. Supercharging methods are outlined, including forced and supplemented induction, scavenging and the use of the two-stroke cycle.

With respect to the different methods used in supercharging different designs are illustrated and their special features are explained. The historical data presented include stationary as well as automotive engines and show that supercharging in some form or other has been employed as far back as the gas-engine can be traced. Aircraft, Diesel and racing engines are considered, as well as those for passenger cars.

Regarding supercharger development for passenger-car engines, the author suggests the possibility of designing a supercharger that will produce greater torque at low speed and enumerates some of the advantages that would result if this were accomplished.

THE DISCUSSION

DR. S. A. MOSS[2]:—Professor Rateau, of France, developed a supercharger for airplane engines during the war. The General Electric Co. had done a great deal of experimental work with centrifugal compressors, steam-turbines and gas-turbines and, since the supercharger is a combination of all of these, the American Air Service authorities asked the company to make experiments similar to those made by Professor Rateau. The same principles that Rateau had made use of were utilized, but the actual details of design followed the practice of the General Electric Co. for centrifugal compressors and steam-turbines. Professor Rateau has since developed his machine completely, in France, and we have continued our development in the United States. Each type of machine differs from the other in detail.

Fig. 1 shows the first American-built supercharger, installed on a Liberty-12 engine in May, 1918. The centrifugal compressor of the supercharger is shown at the front end of the engine. At the rear, not shown, is a turbine-wheel driven by the exhaust-gases of the engine, and this wheel drives the centrifugal compressor.

Fig. 2 shows how the airplane-engine supercharger operates. The exhaust-valve chambers are connected to

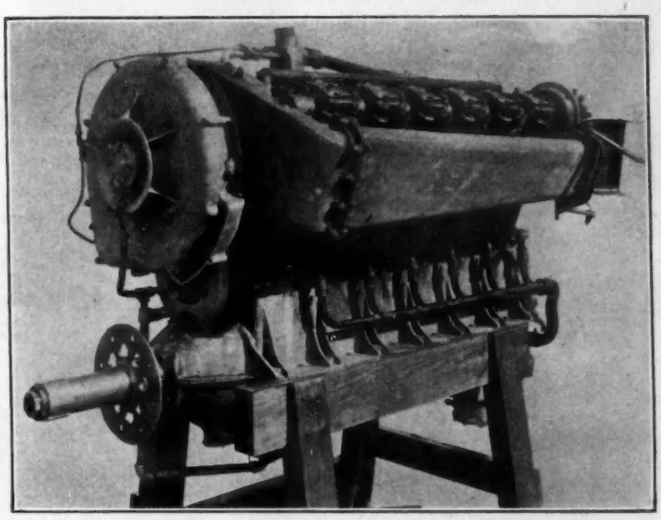


FIG. 1—FIRST AMERICAN-BUILT SUPERCHARGER WHICH WAS INSTALLED IN MAY, 1918, ON A LIBERTY-12 ENGINE

The Centrifugal Compressor of the Supercharger Is Shown at the Front End of the Engine. At the Rear, Not Shown, Is a Turbine-Wheel Driven by the Exhaust-Gases of the Engine, and This Wheel Drives the Centrifugal Compressor

[1] M.S.A.E.—Chief engineer of the mechanical engineering section, General Motors Corporation Research Laboratories, Detroit.

[2] Engineer, Thomson Research Laboratories, General Electric Co., West Lynn, Mass.

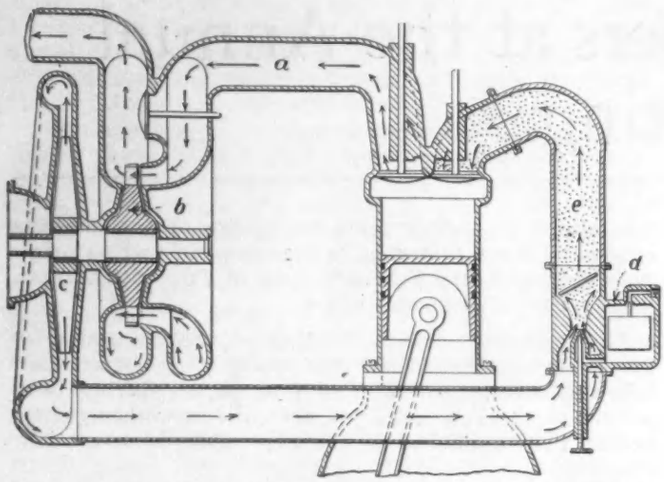


FIG. 2—TYPE OF SUPERCHARGER SUITABLE FOR AIRPLANES CAPABLE OF FLIGHT AT GREAT ALTITUDES

At Great Altitude, Air Is Too Thin and the Airplane Engine Develops Proportionally Less Power. The Supercharger Supplies Dense Air as if the Engine Were at Sea-Level. The Exhaust-Valve Chambers Are Connected to an Exhaust Manifold, Which Supplies Gases to Nozzles That Direct These onto a Turbine-Wheel. The Turbine-Wheel Drives the Centrifugal Compressor, Which Takes In and Compresses Air and Discharges It to the Carbureter and Thence to the Intake Manifold of the Engine

an exhaust manifold, *a*, which supplies gases to nozzles that direct these gases onto a turbine-wheel, *b*. The turbine-wheel drives the centrifugal compressor, *c*, which takes in and compresses air and discharges it to the carbureter *d* and thence to the intake manifold *e* of the engine.

At an altitude of 20,000 ft., the pressure of the atmosphere surrounding an airplane is about one-half of that at sea-level. At an altitude of 35,000 ft., the surrounding atmospheric pressure is about one-quarter of that at sea-level. At these great altitudes, full sea-level pressure is maintained in the exhaust manifold when such a supercharger is used. Outside of the turbine-wheel, the reduced pressure due to the great altitude exists. The exhaust-gases pass through the nozzles at a high velocity due to the pressure difference and impinge on the turbine-wheel. This serves to compress the air from the low pressure at the great altitude to full sea-level pressure, which is maintained in the carbureter intake-manifold, so that the engine receives its charge at full sea-level pressure. Therefore, in spite of the fact that the airplane is working in a region having

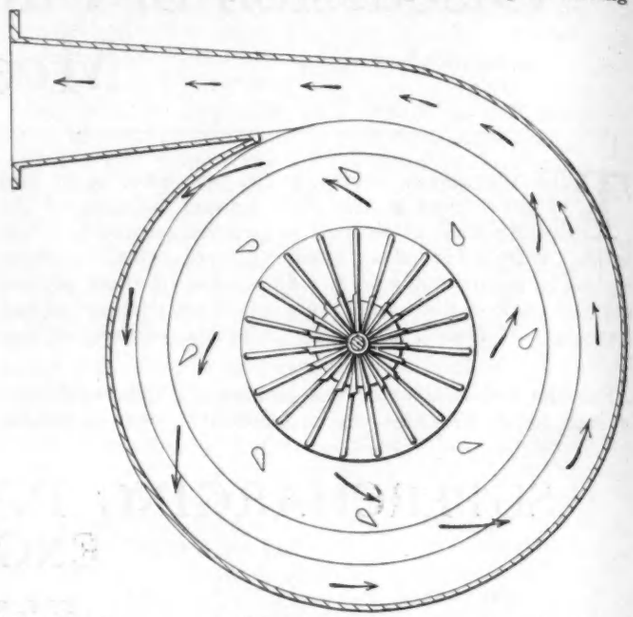


FIG. 4—DIAGRAM OF AN IMPELLER, A DIFFUSER AND A COLLECTING PASSAGE

The Air Enters at the Center against Vanes Designed To Receive It without Shock. At the Periphery of the Impeller There Is a Certain Pressure Due to Centrifugal Force Which Is about One-Half to Two-Thirds of the Final Pressure. At the Periphery of the Impeller the Air Is Moving at a High Velocity Also, Although Velocity Is of No Particular Value Because It Is Much Higher Than the Velocity in the Pipe Which Receives the Final Air. However, the Velocity Represents Power That Has Been Put into the Air. The Diffuser Transforms This Power, Represented by Velocity, into Power Represented by Pressure That Can Be Utilized

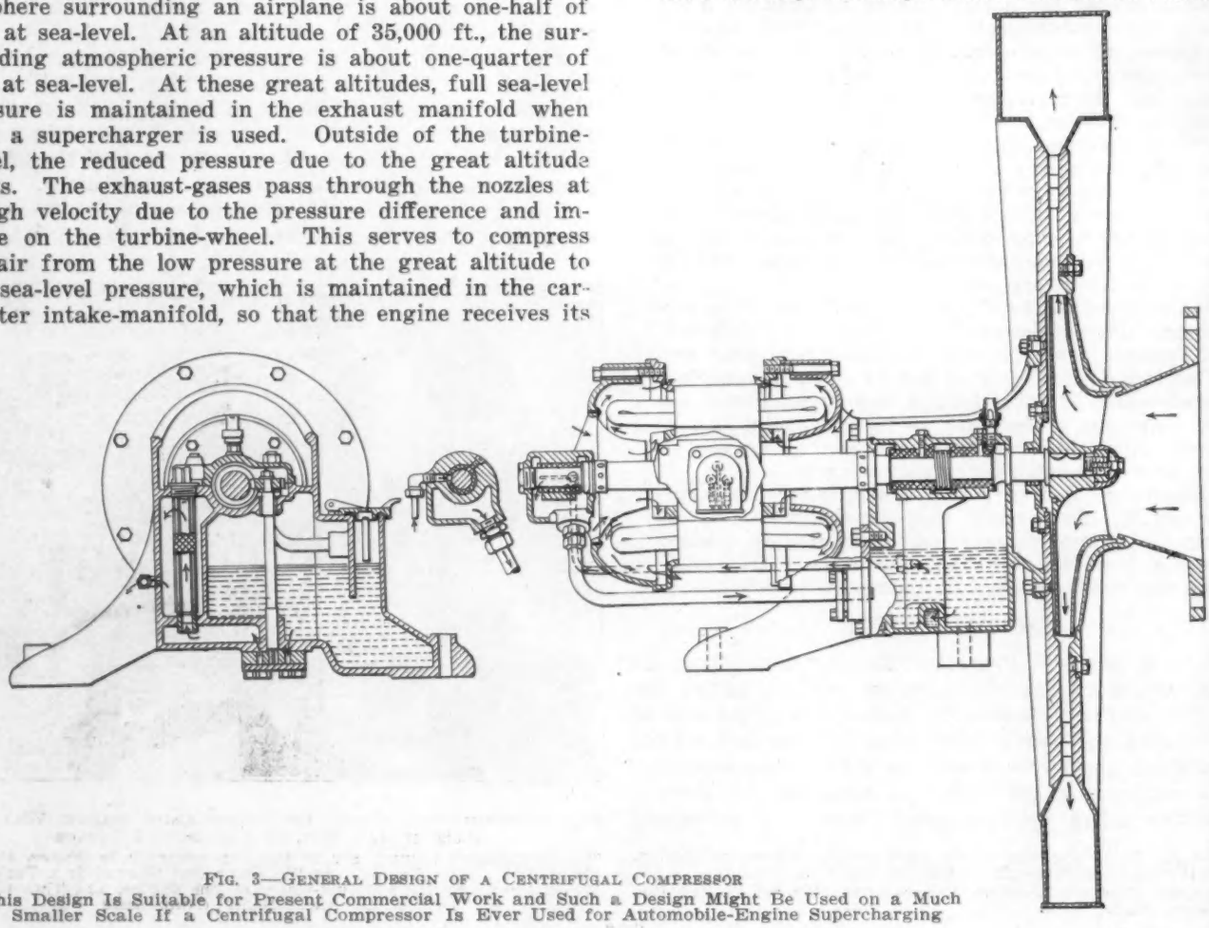


FIG. 3—GENERAL DESIGN OF A CENTRIFUGAL COMPRESSOR

This Design Is Suitable for Present Commercial Work and Such a Design Might Be Used on a Much Smaller Scale If a Centrifugal Compressor Is Ever Used for Automobile-Engine Supercharging

a pressure of ¼ or ½ atmosphere, the engine exhausts and receives its charge at full sea-level pressure. Hence, the engine is not affected by the great altitude and so delivers full sea-level power.

When the theory was first promulgated, many automobile-engine experts were incredulous and expressed grave doubts of its possibility, thinking it a means similar to lifting oneself up by one's boot straps. However, ample power exists in the pressure difference of the exhaust-gases, from sea-level pressure in the exhaust manifold to the pressure of the surrounding region at great altitude, to accomplish the result described.

The original solution proposed for flying at great altitude was to use an engine having large displacement, so that it would take a full charge equivalent to a sea-level charge, even though at great altitude. At that time no large airplanes existed, but large ones have been built since and it is now possible to use an 800-hp. engine in an airplane and to fly it at great altitude so as to obtain 400 hp. The 800-hp. engine weighs about 1200 lb. and the 400-hp. engine equipped with a supercharger weighs about 850 lb., the weight of the supercharger being about 150 lb. The difference in total engine-weights illustrates why superchargers are used for great altitudes rather than over-sized engines. Whether the same thing will happen with an automobile engine is a future problem.

Supercharger Compressors and Diffusers

A part of all superchargers is a compressor of the displacement, the vane or the centrifugal types. The General Electric Co. manufactures centrifugal compressors because it believes that type is superior to vane and to displacement compressors. Fig. 3 shows the general design for present commercial work and such a design might be used on a much smaller scale if a centrifugal compressor is ever used for automobile-engine supercharging. Present commercial machines are driven by electric motors or by steam-turbines for supplying compressed air at pressures of 1 to 30 lb. per sq. in. for various purposes. Between the impeller and the collecting scroll is the diffuser, which is also an important part of the design of any centrifugal compressor.

Fig. 4 is a diagram of an impeller, a diffuser and a collecting passage or scroll. The air enters at the center against vanes designed to receive it without shock. At the periphery of the impeller there is a certain pressure due to centrifugal force which is about one-half or two-thirds of the final pressure. The air at the periphery of the impeller is moving at a high velocity also, although velocity is of no particular value because it is much higher than the velocity in the pipe which receives the final air. However, the velocity represents power that has been put into the air, and the problem is to transform this power, represented by velocity, into power represented by pressure which we can use. The diffuser does this.

The diffuser slows down the air so that the velocity is decreased and, if this process is accomplished effectively, a rise in pressure will result. In other words, at the beginning of the diffuser passage the air has a certain pressure and considerable velocity. It passes through the diffuser, which gradually decreases the velocity and increases the pressure. The air has to be coaxed very carefully because it resists having its pressure increased.

Some of the diagrams of different kinds of vane which were described by Mr. Short, called diffusers, would accomplish no diffusion; the air would lose its velocity but there would be no pressure-rise. A diffuser must be proportioned very carefully to suit the service for which

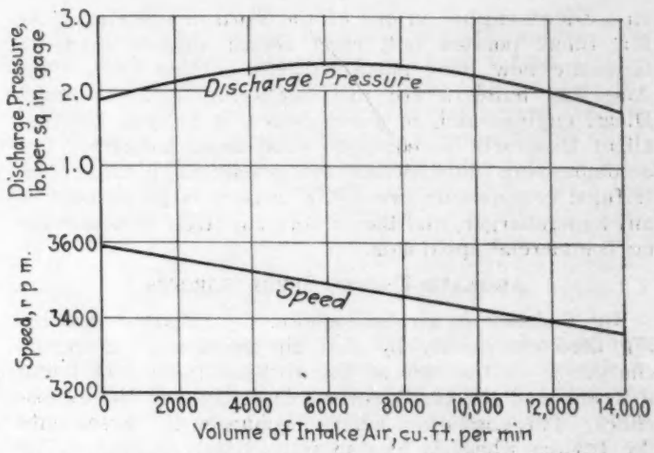


Fig. 5—Pressure Produced by the Type of Diffuser Shown in Fig. 4

With Any Usual Driving Means, as the Load on the Compressor Increases, the Speed Decreases Somewhat. As a Result of This Decrease of Speed and of the Design of the Diffuser, the Compressor Has a Pressure as Shown by the Upper Curve

the compressor is designed. Certain velocities and certain rates of change of velocities must be secured, constituting a complicated problem.

Fig. 5 is a diagram of the pressure produced by the type of diffuser mentioned previously. With any usual driving means, as the load on the compressor increases, the speed decreases somewhat. As a result of this decrease of speed and of the design of the diffuser, the compressor has a pressure as shown by the upper curve. It is practically a constant pressure for all volumes of air.

The commercial compressor having a single inlet is used for volumes up to a certain amount but, for larger volumes, it is not possible to take in all the air on one side of the impeller and then it is taken in on both sides.

All centrifugal compressors operate best at high speeds, but the commercial electric motor does not operate best at high speeds and, to get the best results, it is desirable to use gearing. A geared supercharger is used

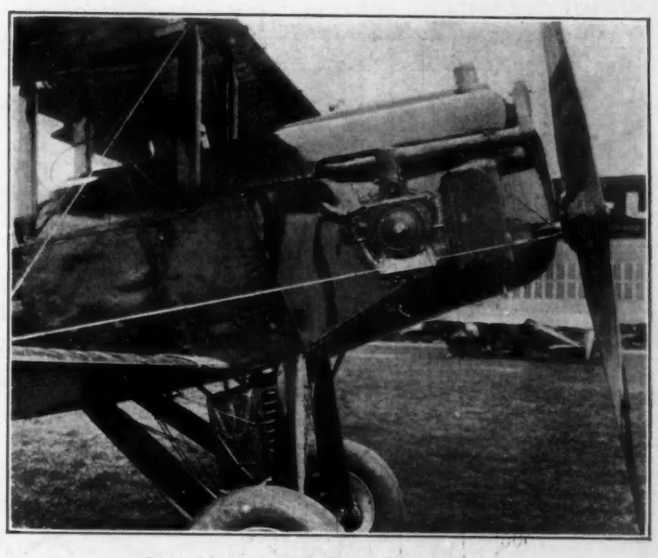


Fig. 6—Airplane Turbo-Supercharger

The Supercharger Is on the Side of the Airplane Instead of Being in Front and the Turbine-Wheel Is Directly in the Atmosphere. The Nozzle Box Which Discharges the Gases onto the Turbine-Wheel Is Immediately Behind. The Blast from the Airplane Propeller Directs the Exhaust-Gas Backward, and the Exhaust-Gases Themselves Have a Slight Velocity Outward So That They Travel Diagonally Back in the Space between the Upper and the Lower Wings

on a Diesel engine on one of the Ford ore-carriers. As Mr. Short pointed out, most Diesel engines made in Germany now have superchargers of this type. The American builders are just beginning to supercharge Diesel engines and, in a few years, it is probable that all of them will be equipped with superchargers. The accompanying illustrations are presented because centrifugal compressors are going to be a large element in any supercharger, and the compressor itself is now regular commercial apparatus.

Airplane-Engine Superchargers

Fig. 6 shows an airplane-engine supercharger now being used extensively by the Air Service. The supercharger is on the side of the airplane instead of being in front, and the turbine-wheel is directly in the atmosphere. The nozzle box which discharges the gases onto the turbine-wheel is located immediately behind. The blast from the airplane propeller directs the exhaust-gas backward, and the exhaust-gases themselves have a slight velocity outward so that they travel diagonally back in the space between the upper and the lower wings.

Fig. 7 shows barograph records illustrating what was done during the early great-altitude work to obtain data for changing the detail design of the supercharger. The records are made by recording instruments on paper wound on a drum and have been reproduced in the illustration with time used as abscissas. The upper line shows the speed of the airplane in miles per hour. The middle line is what is called the engine altitude; that is, it shows the pressure in the intake manifold of the engine, which represents the altitude at which the engine is, in effect, flying. If this intake pressure is that of sea-level, the engine functions as if it were at sea-level and so develops a corresponding power. The lower line shows the actual altitude of the airplane as indicated by a recording barograph.

The flight begins at the left of the chart and, for a time, the engine and the airplane altitudes are identical. Supercharging begins at the point so marked, and then the engine altitude is, in effect, gradually increased until it is somewhat above sea-level, while the airplane is

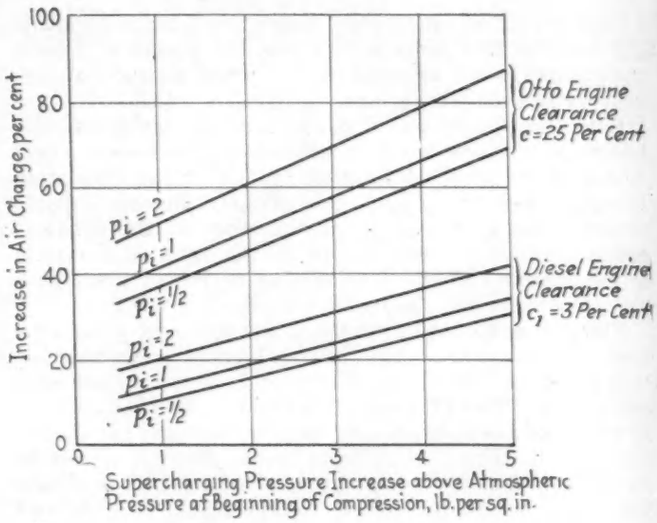


Fig. 8—Theoretical Increase of Air Charge Due to Supercharging

In the Chart P_i Is the Initial Pressure, Without Supercharging, in the Cylinder at the Beginning of Compression, in Pounds Per Square Inch below Atmospheric Pressure

climbing to 18,000 ft. Then there is a short space where the altitude is constant, indicating level flight. The supercharger is then giving a pressure equivalent to that of 1500-ft. altitude when the airplane altitude is 18,000 ft. Then the airplane climbs again and some level flights are made at about 22,000-ft. altitude.

In this particular test there is some stoppage of the gasoline-pump. The supercharger is then disconnected and the engine altitude, in effect, climbs up to and becomes nearly that of the airplane altitude. Then the trouble is corrected and the supercharger is turned on, which again reduces the effective engine-altitude. At 14,000-ft. airplane-altitude, some level flights are made. Then the supercharger is disconnected and the engine altitude, in effect, increases to be that of the airplane altitude. Then the airplane descends without any supercharging. Fig. 7 is really a remarkable chart, indi-

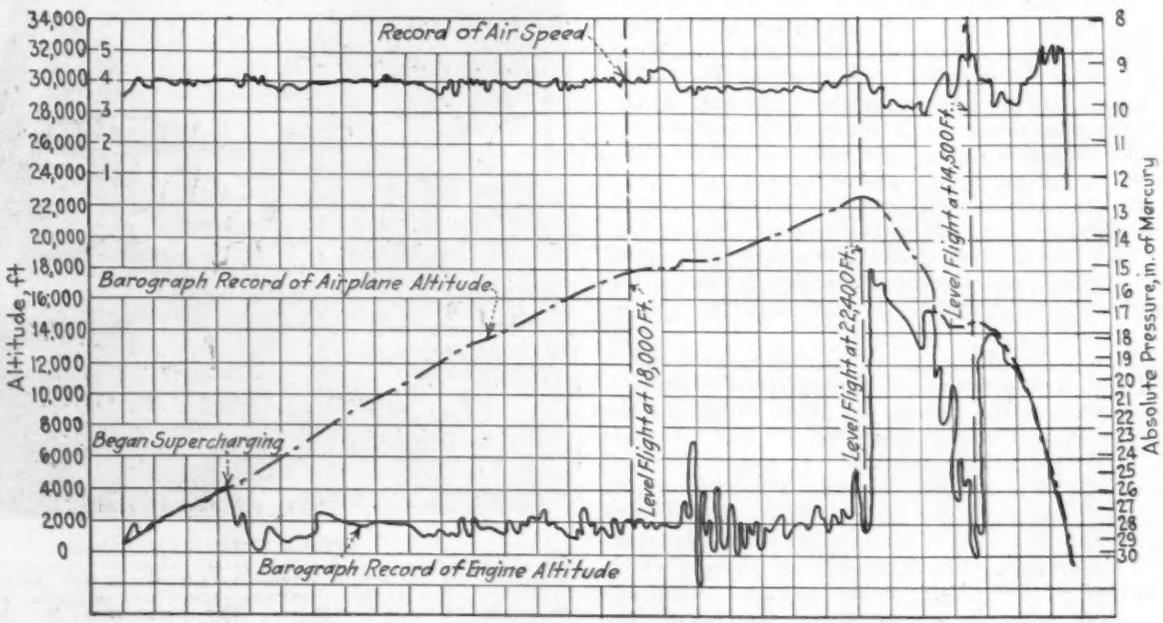


Fig. 7—Graphical Record of the Flight of a Supercharged Airplane at Great Altitudes

This Is a Remarkable Chart That Indicates the Results of a Complete Set of Laboratory Tests Made on an Airplane Engine Under Conditions Equivalent to Those at Great Altitudes

cating the results of a complete set of laboratory tests made on an airplane engine under conditions equivalent to those at great altitudes.

Theoretical Action Due to Supercharging

Fig. 8 shows a diagram that illustrates the theoretical action due to supercharging, but it is not the result of tests of any kind. If supercharging is properly done in either a Diesel or an automobile engine, the clearance space will be filled with a fresh charge. Normally, in any automobile engine, a large volume of clearance space exists which is filled with exhaust-gases and never has a proper charge. If the supercharging pressure is made somewhat higher than the exhaust-manifold back-pressure, and if the valve-timing is properly adjusted so that there will be a period at the end of the exhaust stroke and the beginning of the intake stroke when both exhaust-valve and inlet-valve will be open at the same time, then, the higher pressure of the intake manifold can scavenge the clearance volume and fill the clearance volume as well as the displacement with a supercharged charge. This actually has been done in the Diesel engine, and it means a considerably greater increase in power than would be accomplished merely by supercharging the displacement volume.

In Diesel engines, there has been a remarkable gain with supercharged engines due to a better mixing of the components of the combustion. If the supercharged air has a high velocity and the exhaust is introduced at the proper time, there results a clean charge around the upper end of the cylinder, where the ignition first starts, and this improves the combustion. A similar result has been claimed for automobile, airplane and other Otto-cycle engines using gasoline. Whether that gain will be obtained or not is a subject for further experiment.

Fig. 8 takes no account of such gains and merely shows the increased weight of charge and the power gain thereby, with no improvement in combustion. It shows, for instance, that Otto-cycle engines with 4 lb. per sq. in. supercharger pressure give an increase in power of about 55 per cent. As Mr. Short stated, such an increase of power has been accomplished, actually, and Otto-cycle engines have been operated in the United States with 30 to 50 per cent more power from a given cylinder than it is possible to attain without a supercharger.

Displacement versus Centrifugal Superchargers

H. A. Huebotter[3]:—Two types of supercharger exist, the positive displacement and the centrifugal types. The type used and the manner of its installation depend mainly upon what performance we demand from an engine.

One especially good point brought out in C. W. Iseler's paper on the Practical Application of Superchargers to Automobile Engines[4] was that the Roots type of supercharger on the Mercedes engine did not have much effect in high gear. He says that:

> On high gear the car accelerated from 10 to 30 m.p.h. in 10 sec. with the supercharger while, without the supercharger, the time required was 13 sec. Acceleration time on intermediate gear for the same range was 4.0 sec. with the supercharger and 6.8 sec. without it.

That was 23-per cent reduction in time for high gear and 41-per cent reduction for second gear. In other words, the supercharging improved with the increase in engine-speed. This shows that for high torque at low engine-speeds, which we need for acceleration or hill climbing, the supercharger probably was geared too low or had too small a capacity for the engine. On the other hand, if we want high speed alone, we would get it with that gear-ratio and that speed. Consequently, with the supercharger, we can use ordinary low-speed valve-timing and we get good performance at high speeds as well as at low speeds. We do not need a compromise in valve-timing to get good performance over the full range of the engine-speed.

The centrifugal type of supercharger has been shown here mainly in its single-purpose application. In all instances, they are used under nearly constant speed and delivery conditions. We do not have those conditions in the automobile engine, although we approximate them in the racing car and in the airplane engine. So far, we have seen nothing in the way of applying the centrifugal supercharger under variable-speed and variable-load conditions.

It seems to me that the use of a supercharger is unreasonable for part-load applications. When not operating at full throttle a supercharger is not needed, since the only purpose of the throttle is to cut down the intake pressure at the valves. There is, however, a case for the centrifugal supercharger if it is put between the carbureter and the inlet-valves, to promote the uniformity of distribution at all speeds and at all loads. I believe that they have experimented at McCook Field and have obtained very good results with the simple rotary induction-system, which does not supercharge but simply rotates at somewhat higher speed than that of the air-velocity and thereby breaks-up the fuel drops and gives better uniformity to the charge.

Positioning of the supercharger involves one other matter. If we use the supercharger only at full load, and cut it out at part throttle, we must locate it on the inlet side of the carbureter; otherwise, it would constitute an obstruction in the manifold system. If we supercharge the inlet side of the carbureter, we must seal-off the float-chamber from the atmosphere and air-bleed into the mixing-chamber to get the flow of fuel from the chamber to the nozzle. If we supercharge in that way, we must build-up a high pressure for the fuel from the tank to the carbureter. That will introduce a mechanical complication which will affect the carbureter design materially.

Question:—In the multiple-stage compressors mentioned by Dr. Moss, does the pressure rise in direct ratio?

Dr. Moss:—It is a geometric ratio, the absolute pressure multiplied by a constant factor.

Noise and Knocking Tendencies

C. F. Taylor[5]:—Optimism in regard to supercharging passenger-cars is evident, but very little is known about it. Increased interest in supercharging should result from this meeting and perhaps this will stimulate some of the research laboratories to determine what can be accomplished by the combination of the present knowledge of engine performance with that relating to the various types of supercharger, particularly for the points at which the engine has low torque.

To say that the supercharger increases efficiency seems misleading to me; perhaps it would be better to say "power." Efficiency depends, not on the compression-ratio but on the expansion-ratio. We have been accustomed to say that efficiency depends on compression-ratio because of the fact that in normal engines the compression-ratio and the expansion-ratio are the same. If we

[3] M.S.A.E.—Research associate professor, Purdue University Engineering Experiment Station, Lafayette, Ind.

[4] See The Journal, May, 1926, p. 518.

[5] M.S.A.E.—Associate professor of research in aeronautical automotive powerplants, Massachusetts Institute of Technology, Cambridge, Mass.

supercharge, we increase the actual compression-ratio but we do not increase the expansion-ratio; therefore, it can hardly be assumed that the efficiency will be increased.

In regard to passenger-car applications of the supercharger, certain important problems must be worked-out. The noise problem is a very serious one. I have operated many different types of supercharger and most of them proved to be extremely noisy. The low-speed positive-displacement supercharger is the only one that is comparatively free from noise, and this type is bound to be very bulky and heavy. Another difficulty is due to the fact that, under conditions where supercharging would be useful, most automotive engines are already working at the maximum pressure which the fuel will withstand without severe detonation. It usually is impossible to increase the compression pressure without increasing the knock, and whether the improvement in mixture which can be obtained by some methods of supercharging that will allow an increase in the compression pressure without increasing the knock is another question which has not yet been answered.

C. R. SHORT:—The exhaust-valve does not open at the same time as in standard timing, if a supercharger is to be used. It is opened at a certain pressure to overcome the resistance or back pressure in the exhaust-line. That pressure occurs at a lower point of the stroke. The heat-loss is less when a supercharger is used, but the compression-ratio remains the same. The area of the combustion-chamber space is varied to obtain some predetermined compression-pressure ratio, and the fuel determines how high that ratio can be. If a cylinder actually were filled at the closing of the intake-valve, there would be a larger compression space than at present. The compression space is limited now because the cylinder does not get a full charge.

DR. MOSS:—If a diffuser is particularly designed to suit a given automobile engine or a given airplane engine, even at variable speed, arrangements can be made so that most operating points come at the flat part of the efficiency curve near its peak. If, however, the proper design is not used, then operation may occur at a point on the efficiency curve far removed from the peak, where the efficiency will be low.

SUPERCHARGER-DEVELOPMENT HISTORY

DAVID GREGG[6]:—During a period of about 4 years I was in charge of supercharger development for the Air Service at McCook Field, and designed the first supercharged induction-system used on the Duesenberg car that won the 1924 Indianapolis race. To the best of my knowledge, the first work on turbo-superchargers was done by Professor Rateau in France. In 1917, at the suggestion of Dr. Durant, the Government selected Dr. S. A. Moss of the General Electric Co. to develop a similar supercharger in this Country. Dr. Moss designed the Form-A supercharger which was tested on Pikes Peak, and which was used by Major Schroeder in making his first world's altitude-record with a supercharged airplane. Further development of the turbo-supercharger and of the present side-type turbo-supercharger is the work of Government engineers at McCook Field, assisted by the manufacturing facilities of the General Electric Co. The various developments were conceived at McCook Field, where all the practical testing was carried out, and the preliminary drawings were made under the direction of Government engineers. The General Electric Co. then detailed the drawings and completed the manufacture. Adolph Berger, formerly supercharger foreman and now in charge of this work, deserves great credit for the present mechanical perfection of the turbo-supercharger.

At the time the first General Electric Co. supercharger was submitted for test, E. H. Sherbondy also submitted a turbo-supercharger for the Liberty engine. Unlike Dr. Moss, he permitted his tests to be made at the low altitude of Dayton and had little success; hence, his supercharger was not developed further. In the light of our present knowledge, it seems that the Sherbondy design was more refined than that of the General Electric Co., and would have been successful had it had the same amount of further development and test that the General Electric Co. supercharger had.

The first gear-driven supercharger submitted to the Air Service, aside from the development work carried out in the American Expeditionary Force by M. LeBlanc and Captain Kerr, was a vane blower by Pense, which was not successful. The next was a gear-driven centrifugal-compressor designed by H. E. Morton, of the B. F. Sturtevant Co. This supercharger was a very interesting design that incorporated an oil clutch to reduce the acceleration load on the impeller. The design was rather too complicated for the Air Service to develop, although it had many interesting features.

The first gear-driven supercharger of the type now in use was designed by McCook-Field engineers, and this development resulted in the present geared superchargers of 10,000 and 20,000-ft. altitude-rating used by the Air Service. The General Electric Co. then submitted a geared supercharger with a double step-up gear-drive consisting of three sets of gears mounted in plain bronze-bearings. The compressor part was of conventional design, but so much trouble was experienced with the geared drive that the design was discarded.

The successful development of geared superchargers was brought about by the development of light-weight aluminum-alloys and by the development of anti-friction bearings that will operate successfully at speeds of 30,000 r.p.m. Reducing the moment of inertia of the moving parts is of the utmost importance.

The original turbo-superchargers had impellers made of steel. When the first Air-Service gear-driven design was made, a similar impeller made of forged duralumin was used. The next step in lightening the impeller was to scallop between the blades. Then, forged magnesium was used successfully. Although of less strength than forged duralumin, the strength-weight ratio is nearly the same, and it is on this ratio that the factor of safety of the impeller depends. Later, an impeller was made of cast magnesium, and this also proved amply strong. It is evident that it will soon be possible to make impellers of die-cast magnesium, requiring practically no machine work to finish. The Aluminum Co. of America and the American Magnesium Co. were of great assistance in carrying-out the development of impeller material.

Ball-bearings and roller-bearings continually failed at speeds around 20,000 r.p.m.; but, after 3 years of testing at McCook Field, ways of mounting and lubricating the bearings have been developed so that they have operated more than 200 hr. at speeds above 30,000 r.p.m.

Superchargers are by no means limited to automobile or to airplane engines. In the course of my consulting engineering work during the last 6 months, I have applied superchargers to marine and to Diesel engines and to motorcycle engines as well. In the marine field, particularly for high-speed runabouts and racing boats, a

[6] Dayton, Ohio.

keen demand for superchargers exists. Swiss engineers, in particular the firm of Brown, Boveri & Co., have used turbo-superchargers and electrically driven superchargers on Diesel engines for a number of years. The Hamburg South American liner Monte Sariento and her sister ship Monte Olivia are so equipped. The pressures used are between 6 and 7 lb. per sq. in. above atmospheric pressure.

METALCLAD RIGID AIRSHIP DEVELOPMENT

BY RALPH H. UPSON[1]

ABSTRACT

SEVERAL years ago some of the most prominent leaders in automotive industries cooperated to form a purely engineering group that had as its primary purpose developing a type of rigid-airship construction in which the public would have confidence. It was conceived that such an airship should be

(1) Fireproof
(2) Weatherproof
(3) Durable and permanent in structure
(4) Navigable in practically all kinds of weather
(5) Economical in the use of buoyant gas and ballast

To meet all of these requirements it was decided, after mature consideration, that a substantially all-metal construction was imperative. Development of the Metalclad airship has now reached a point where the general soundness of the design seems fully assured as

(1) The structural and aerodynamic efficiencies have been established by both analytical and experimental methods
(2) The technical problems involved in the construction have been mastered to a certainty hitherto unapproached in any new design
(3) The general design of an airship of demonstration size, 200,000 cu. ft. or one-tenth the size of the Shenandoah has been completed
(4) Full-sized structural members of every part of the framework have been built and tested to destruction revealing that the minimum safety factor is double that of the Shenandoah. The longitudinal strength of the metal hull will be more than four times as great as that of the Shenandoah
(5) The problem of riveting the metal hull-plating has been solved through the perfection of an automatic riveting-machine
(6) The problem of making the metal hull gas-tight has been solved with surprising efficiency indicating an osmosis of about one-tenth that through gold-beaters skin and only one-hundredth that through rubberized fabric
(7) A suitable coating to prevent corrosion has been satisfactorily tested
(8) A source of supply of aluminum alloys of dependable quality is assured
(9) Shop facilities for fabrication are available in Detroit
(10) Skilled metal-workers familiar with aluminum and its alloys are at hand

These results depend upon certain fundamental principles that are described in the paper. In effect, the design is an entirely new one, but adheres to the fundamental unalterable principles underlying all sound engineering-work.

The paper states that the Metalclad airship is the last step in the development of rigid airships and most certainly must be adopted if such a means of transportation is to be made available both for the arms of National Defense and for commercial purposes.

Appendices that include extracts from studies and texts arranged to illustrate the subject matter in the main paper and furnish food for discussion supplement the paper. This material is partially elementary in form as limitations of space preclude any attempt at completeness.

THE DISCUSSION

DR. KARL ARNSTEIN[2]:—I am sorry that the paper which Mr. Upson has just presented did not come to my attention until a few days ago. I acknowledge Mr. Upson's courtesy in sending me a preliminary copy, on which I have prepared the comments that I shall read to you now.

I congratulate Mr. Upson on his efforts and the research work done toward the realization of the problem of the all-metal airship. Airship development needs unselfish pioneers with optimism and enthusiasm like Mr. Upson, and I hope that he may have as much success as there may ever be possible in his line of effort.

But I believe that it would be highly inadvisable to follow Mr. Upson's implied suggestion to stake all efforts for the immediate future on this experimental type and to suspend all work toward further development of ships of a type proved through 25 years of successful operation.

Experience has shown that successful development always has been gradual and always has been carefully based on previous experience. It is unnecessary for me to mention the history of rigid airships and to show that radical changes always were unsuccessful and were followed by alterations that more or less led back to the proved type.

A careful examination of Mr. Upson's premises forces the conclusion that there is no reason for scrapping all past experience and accepting the Metalclad airship as a proved thing, because his work does not seem to be based on a really exhaustive appreciation of Zeppelin experience.

The Metalclad project takes it for granted that a fabric cover must be unsatisfactory, especially as regards deterioration and inflammability, and that considerable improvement can be made by substituting metal. We can state from experience that we do not know of any better material for the outer covering of an airship than our combination of fabric, dope and metal.

Let us first deal with the question of deterioration. It is evident that the sun and other weather influences, particularly humidity, will gradually affect the fabric that forms the basic material for the outer cover and the gas cells of the ship. But it has never been necessary to replace an outer cover of a Zeppelin airship, although even on these earlier ships the modern methods of protecting the fabric by dope and metallization were not used and such ships were in service for 4 and 5 years.

For instance, the outer cover of the commercial airship,

[1] M.S.A.E.—Chief engineer, Aircraft Development Corporation, Detroit.

[2] Vice-president, Goodyear Zeppelin Corporation, Akron, Ohio.

Viktoria Louise, which was made without protective dope coating, was still satisfactory after 4 years' service, making four passenger trips a week. The outer cover of the commercial airship Bodensee, which is now 6 years old, is still in excellent condition. Later developments brought the use of metals in the fabric, as in the Los Angeles. Her outer cover, although now 2 years old, is still as good as new, notwithstanding the influences of the trans-Atlantic flight and the excursions to the West Indies and Bermuda.

We expect, therefore, the future type of outer cover, which will be a composite structure, consisting of cotton fabric as a base with various layers of metal and dope coatings, to last in any climate with proper care almost as long as the purely metal parts of the ship's framework.

As to the gas cells of the Zeppelin airship, which are also made of fabric, there is, of course, no question whether the strength will remain adequate, since there are practically no stresses. Their gas-tightness is completely satisfactory with gold-beater skin, if properly manufactured and maintained. The diffusion for gold-beater-skin cells is from 0.0 to 0.3 liters per sq. m. in 24 hr. So far as I am informed, the corresponding figures for metal seams are about the same. These figures are, of course, from laboratory tests, and practical results will be less favorable. But it remains to be proved whether metal seams will stand up as well in tightness under practical operating conditions as does the gold-beater skin.

Improvements of gas-cell fabrics are being worked out. We are developing a substitute for gold-beater skin, which, no doubt, will result in the production of gas cells that will withstand any climatic influences, including tropical conditions.

In addition, by applying a metallization process to it at the expense of only a negligible weight but retaining all the important advantages of fabric, namely, flexibility and pliability, we shall be able to lower, to an almost negligible percentage of the ship's cost, the cost of gas cells, which even now is an unimportant factor, so that liberal replacements will be possible whenever desirable.

The second objection raised against fabric is its alleged lack of fireproof qualities. But it is easy to make a fabric completely fireproof, if desired, by the application of a suitable dope to both sides. It is not essential that the outer cover or the gas cells of an airship should be fireproof. It is sufficient, if they are "non-burning," that is, if they do not sustain combustion on their own account.

A thin-metal sheet is not fireproof. It will melt under the action of flames from an exterior source, and will be affected in the same manner as a metallized and doped fabric cover. The fabric cover will remain intact, where the flames do not reach it, just as well as will the thin-metal sheet. In this respect, we cannot see any advantage of a metal skin over our materials.

The statement is made that a fabric outer-cover is a liability, not an asset, as to strength. It is assumed that the outer cover of a Zeppelin-type ship does not contribute to strength and does not help take stresses. It is true that, in making strength calculations, most designers leave the outer cover out of consideration, but it does not follow that the outer cover is a liability.

Zeppelin-type airships are built to give ample strength and factors of safety even without the outer cover and, in addition, the cover is made a stress-taking part by elaborate means in design and application, so that the actual factors of safety of the ship may be said, in the first approximation, to be about double the values demonstrated by calculation, without taking into account the effect of the cover.

Concerning the ratio of strength to weight, the Zeppelin outer-cover material is even superior to the thin-metal sheet, the figures for the practical stress ratio-limit being 23,000 ft. for duralumin and 30,000 ft. for our doped fabric.

With regard to the Metalclad's outer skin being a permanent and reliable stress-taking part of the structural unit, this is strictly correct only when the outer skin is permanently under internal pressure. Internal pressure with its various disadvantages will therefore be an essential feature in the actual operation of the projected Metalclad ship.

The Zeppelin-type outer-cover is designed, manufactured and applied in such a way that it always remains in a shape to take its part of the stresses without regard to pressure. But there is no reason that the principle of setting the outer cover under internal pressure should be confined to the design of Metalclad airships. We have used it, for instance, in several experimental cases. It is peculiar neither to very fat nor to Metalclad shapes. We need it only as a means of abating vibration, but it seemed inadvisable to us to rely for strength of structure on pressure derived from forward motion, because it might not be at hand in critical moments, if, for instance, the ship were struck by a side gust while being handled from the ground.

The argument is made at times that fabric is liable to tear locally and thus lead to structural damage. Experience with numerous cases of ships damaged by artillery fire shows that, even if tears or punctures are started by an outside influence, there is very little tendency for the holes to increase during flight.

As to electrical conductivity, the electrical properties of gold-beater skin, not to speak of the future metallized materials, are more than amply satisfactory, and from this point of view the introduction of metal would mean useless added weight.

Regarding thermal conductivity, the Zeppelin system, with an insulating jacket-space plus two layers of metallized material, is superior to a single sheet of metal.

It is stated that humidity, that is, rain and snow, will have less influence on the Metalclad. This is probably a misconception, because the Metalclad must rely on a heavy coating of dope for protection against humidity just as the Zeppelin does. In any case, the water absorbed in modern Zeppelin material is practically negligible, anyway.

A superior smoothness of surface is alleged for the metal skin as against fabric. But, in both the Metalclad and the Zeppelin types, the outer surface consists of one of several layers of dope, which are equally smooth in both cases.

We come now to the more important matters of strength and weight. The Metalclad, as proposed by Mr. Upson, has only one skin, which is extremely thin and vulnerable and cannot be supervised and maintained efficiently under practical operating conditions. From practical experience, we may say that a duralumin sheet of 0.008-in. thickness is unsafe for practical operating requirements; and we have banished the use of this thickness and the next one, and even one twice as thick, 0.016 in., from our design and construction. One reason for this is that no positively reliable way exists as yet of preventing corrosion. In addition, metal sheets of 0.008-in. thickness usually have an increased tendency toward corrosion as compared with thicker sizes.

It is hard to keep protective dope coatings in efficient

condition, incidentally, they mean considerable weight, and there is no protection, so far as we know, against intercrystalline corrosion. In our opinion, the use of sheets 0.008 in. in thickness should be prohibited, because of the tendency toward intercrystalline corrosion, until this metal-disease problem is definitely solved.

In any event constant supervision will be indispensable. Although this may be possible with the outer side of the metal skin, supervision, repair and renewal of the coating of the inner side will be practically impossible without regular periodic deflations and, even then, the procedure will remain most difficult. This will, however, be indispensable, since it will be impossible entirely to prevent moisture from condensing on the inside skin, even though means for drying the gas were introduced.

Safety against hailstones, for instance, of a metal sheet of 0.008 in. remains questionable. Safety against lightning, which, for a Zeppelin-type airship, is 100 per cent complete with helium, and almost 100 per cent with hydrogen, is doubtful for the Metalclad, even with helium, since the thin-metal sheeting would probably melt under the influence of an enormous charge concentrated at the point of entrance of the lightning and, in a hydrogen ship, would bring about disaster. With helium, this would lead only to losses of the lifting-gas.

The most serious objections against the one-skin Metalclad system, however, are its extreme vulnerability and the grave consequences for the safety of the ship, following even slight damages in operating. It is, for instance, practically impossible to prevent damages to the hull from objects dropped on it in the hangar or by the carelessness of the personnel in moving on it, or in handling ladders, poles, blocks, and ropes. In these regards, the thin-metal sheet is no better off than fabric, although its local strength may be slightly greater in spite of its inelasticity, but with the Zeppelin ship a damage to the outer skin has no consequences and a quicker and easier repair is instantly possible.

With the Metalclad system, great losses of valuable helium are inevitable, since the gas will blow out immediately from the slightest hole at a high rate of speed, due to the internal pressure; and it will take a long time for even temporary repairs to be made. In flight, the same comparison holds true, any damage to the outer cover of the Zeppelin-type ship can be repaired instantly, and has no bearing on the safety of the ship. For the Metalclad, the consequences for safety may become serious, since no repairs are possible, and since, on account of excessive internal-pressure, a considerable amount of lifting-gas may be forced out before the damage is even detected.

The difficulty of proper repair and supervision is a serious disadvantage for the Metalclad ship. For even ordinary overhaul or repair, the ship must be deflated and, in order to maintain its safety, periodical deflations will be necessary, to make the interior accessible for inspection. The losses of helium from occasional damages, from seams leaking under the influences of vibration and weather, and those resulting from such repeated deflations and reinflations will largely reduce the helium-economy hoped for.

Since there is no possibility of avoiding damages and the resultant repair work and since there is no material likely to be found that is not subject to deterioration and the need of replacement, the principal and by far the most important requirement for the permanent safety of an airship is the possibility of constant supervision, inspection and control of all its parts and the complete accessibility and ease of replacement of any of them. In modern Zeppelin airship design, there is practically not a single part or corner that is not always accessible and where repairs cannot be made instantly and effectively, in most particulars, even in flight.

The mentioned methods of erection and inflation of the Metalclad seem doubtful. How can such an airship be deflated, for instance, for repurification of the helium, and how will it be reinflated? How about the purity of the gas? We cannot help fearing that the suggested procedure of inflating the small ship without a cell by allowing a free level surface of helium to be in contact with air will result in a disastrous impurity of the gas that would badly impair its buoyancy.

Let us now discuss in detail the comparison of the factor of strength safety of a Zeppelin-type ship and a proposed Upson ship. Mr. Upson compares the two types under the following conditions. Angle of pitch of 6-deg. sagging condition under ordinary operation, which represents the condition under which Mr. Upson compared his ship with the Shenandoah.

He claims that, for the Shenandoah, for instance, a factor of safety of 1.68 only is indicated in the top longitudinals. This is erroneous. The lowest factor of safety for the longitudinal strength, considering the simultaneousness of the worst condition regarding loads, rudder and elevator actions, which means aerodynamic forces acting in both planes and fast ascent at the same time, never was below 2. This is a fictitious case of combined stress, which is assumed to be worse than the worst that will ever occur in practice; by aerodynamic forces are meant those due to the aerodynamic angle of attack. That is the theoretical factor only, which does not take into consideration the favorable effect of the outer cover, the gas cells and the network, which in various respects increase the factor of safety from 50 to 200 per cent. The expression, "theoretical factor of safety," is just an abbreviation. Correctly speaking, the use of the term, "factor of safety," in connection with calculations under idealized conditions, is a misconception and should be avoided. In airplane design, a similar controversy has already resulted in the adoption of such expressions as "load factors," which are more reasonable. I wanted to point out that the mentioned figure, 1.68, has nothing to do with the real factor of safety of the ship, which, I said, may be estimated to be 7.00 if compared with Mr. Upson's figure of 9.60.

I do not know where Mr. Upson has obtained the information about this low factor of safety of 1.68, but no doubt exists in my mind that it must have been derived from an incomplete calculation and must have considered the naked framework without the outer cover and the network and positively without considering the favorable effect of the longitudinal tension forces due to the gas pressure. It is necessary to take these favorable forces into consideration, at least partly, for the Zeppelin-type, as the safety of the Upson type is based mainly on the effect of the tension forces produced by the gas pressure.

But even under a very conservative calculation, I have found in the above-mentioned case a factor of safety of 3, which increases to 6 or 7 if the favorable influence of longitudinal tension stresses is taken into account. The factor of safety of 7.0 of the Shenandoah must be compared with the expected factor of safety of 9.6 of the proposed Upson ship.

But we must still keep in mind that the actual stresses in the Shenandoah type are lower than this figure on account of the effect of the outer cover and the net-work, according to many tests conducted on British, American

and German ships. The factor of safety of 9.6 of the Upson ship takes all these favorable conditions into consideration, because of its being based on model tests and because of the hull's being of the "single-cover" type, which has only one cover for the three purposes: (a) retaining the valuable lifting-gas, (b) forming the smooth surface of the shape and (c) building the supporting framework.

The Zeppelin ship uses three separate covers serving mainly for each of these purposes, thus protecting the highly valuable gas-containers by framework and outer cover and leaving a most valuable air-space between them.

Regarding the strength of the entire craft, there is a simultaneous action of all the parts corresponding to their elasticity. It is therefore incorrect to base the factor of strength safety on one of these three covers only. Dividing these functions has the advantage that, in case of damage, one structural part may replace another. In the case of the Upson ship, a damage to the single cover damages the gas-container and the supporting framework and might even wreck the entire ship.

I wish to state that the disaster of the Shenandoah was not due to any causes inherent in the specific Zeppelin-type design, as was revealed by the findings of the court, and is in no way a contradiction to the statements already made regarding the factor of safety in the case considered by Mr. Upson.

Thus far, I have referred only to previous Zeppelin designs. In order to have a fair comparison with the future Metalclad, future improvements in Zeppelin design should also be taken into account. I do not intend to discuss how future Zeppelin-type ships will be built and what improvements have been developed there beyond the safety of previous types but will confine myself to mentioning briefly two new features that are most remarkable, namely, the improvement of the strength of duralumin girders by 50 per cent, due to excellent cooperation of the American metal industry and a change in design by using from two to four longitudinal corridors in combination with stiff transverse frames without wire bracing and including the corridor sections. These give extraordinary strength, even in case of failure of a large part of the hull, and allow access to each part of the ship, thus giving a chance to inspect and repair parts of the ship even during flights. These developments are the result of research and investigation lasting over the last 5 years.

Then there is the problem of shape and resistance. We agree with Mr. Upson that it is the skin-friction part of resistance which decreases relatively with the increase of the dimensions. That is what we call the "scale effect." But, in a slender ship, a larger percentage of the whole resistance is friction than in a fat ship. A slender ship, therefore, should be expected to benefit more from "scale effect" than a fat ship, the resistance of which is to a greater degree shape drag, which is known to follow the square law more closely. This is in agreement with the theory of friction due to turbulence.

Our vast full-size experiments on scores of former ships, the model tests in the Zeppelin wind-tunnel, which is 10 ft. wide and has a wind velocity up to 110 m.p.h., and careful studies of the experiments of other investigators, have convinced us that the prediction of airship resistance is a very complicated matter and that it is unreliable to extrapolate from a few observations taken at low Reynolds number. Although in some cases this procedure happens to give fair results, in other cases it might be a complete failure. We believe in the value of wind-tunnel tests, but they require knowledge and experience of many other things in order properly to evaluate them in the prediction of airship performance. According to our knowledge, tests rather indicate that the predictions of performance of the Upson project are very optimistic and that full-sized ships of such fatness will prove to be inferior in resistance to ships having a fatness ranging between 5 and 7.

We assume that the resistance prediction in Mr. Upson's project was based largely on wind-tunnel tests taken at Reynolds numbers not exceeding 250 sq. ft. per sec., whereas some of our experiments, which extend far higher, show that, with fat models, a change of the velocity coefficient sometimes occurs even beyond 300 sq. ft. per sec. On the other hand, determination of the resistance of airship models is very largely affected by the method of suspension used in the wind-tunnel. The so-called spindle method usually gives an interference that increases with both the speed and the fatness and thus is likely to mislead in favor of fat ships.

If Mr. Upson had said:

> As the Metalclad ship requires a fairly short and compact hull and as the model experiments did not show a prohibitive inefficiency of very fat hulls with respect to resistance, we intend to give fat ships a trial.

we should not have objected.

Then comes fatness and stability. Mr. Upson states that no satisfactory method has yet been devised of reproducing or allowing for the dynamics of curved flight in the wind-tunnel. We dare amend this to say, "has not yet been published," for we did devise and use a method and found it highly satisfactory. The figures given in his statements about the combination effects of fatness and fin efficiency are misleading.

It is well known that theoretically the inherent unstable moment is smaller for the fatter ship, but the decrease is a few per cent only, within the range that may be considered as practical and is mainly outweighed by the shortening of the leverage of the tail-fin surfaces with respect to the third root of the volume. This conclusion not only is based on theoretical consideration but is supported by wind-tunnel tests.

Regarding the arrangement of the fins, many variations have been suggested and tested. It is well known and theoretically understood, for instance, that the efficiency of the fins increases with the increase of span and the ratio of span to length, but practical reasons, such as the dimensions of the hangar and ground maneuvers, hampered the application of fins of large span.

Regarding the claimed superior stability of the Upson ship, it is necessary to mention that Mr. Upson plans relatively large amounts of movable rudder-surface. This is not a characteristic of the Metalclad ship. Increase of rudder surface in any ship would result in decreasing the angles of rudder necessary for steering, but the question is only whether it is desirable to give the ship more stability or more maneuverability.

Regarding the use of more than four fin-units, this idea may contain advantages in some respects and disadvantages in others. But this suggestion has nothing to do with the characteristic of the Metalclad ship, unless the Metalclad requires more than four units in order to avoid too concentrated local forces acting on the hull.

We believe that this arrangement of fins, while less economical, especially in full-sized ships, due to the greater number of structural elements necessary, may involve structural complications and greater weight.

The unstable moment, which still remains indicated by

regular wind-tunnel tests on airship models after the fins have been attached, is often used for comparison of the merits of different fin arrangements. This procedure is justified only so far as ships of similar fin arrangement are concerned. In fact, it is not this remainder of unstable moment under pitch that is decisive for the stability in flight, but it is the so-called dynamic stability that takes the important rotary derivations into account. These are more favorable with slender ships. It is known that the stability of an airship in curvilinear motion depends on the location of the center of sway, which is not identical with the center of gravity. It remains to be demonstrated how the dynamical stability will be affected by the peculiar shape of the fins. From what I have explained it should result that, since some rather important points of Zeppelin design have apparently been misunderstood by Mr. Upson, it would be premature to expect any radical changes in the field of airship construction. I feel, however, that some of the problems, the riveting of metal seams, for instance, have been solved by Mr. Upson and his collaborators with remarkable ingenuity, and that further work will lead to important improvements in lighter-than-air ships.

I wish, therefore, to express repeatedly my hopes and wishes that Mr. Upson may succeed in building an experimental ship according to his ideas, which, I am sure, will be to the benefit of all lighter-than-air designs.

R. H. UPSON:—Dr. Arnstein has brought up so many technical points, many of them much more in detail than I had expected to enter into here, that it will be very hard to cover them as they should be covered; but all the more general points, I think, can at least be touched upon.

I am very sorry if I have given anyone the impression that I was advocating the scrapping of all past experience, particularly such very valuable experience as has been contributed by the Zeppelin organization. I trust this will be sufficient apology on that score.

Dr. Arnstein's reference to "radical changes" presumably does not apply to the inception of the Zeppelin type of construction, unless perhaps Dr. Arnstein wishes to cite the failure of the first Zeppelin as a horrible example to anyone else who should dare to transgress the bounds of conventional design.

Estimates of the depreciation of fabric seem to be many and varied. Naturally, I give the greatest credence to those obtained from practical experience, such as is presumably within the Zeppelin files.

Five years ago in my paper[9] read before the Society on the future of airship transportation, I estimated a general factor of depreciation of 30 per cent per year, which has since seemed very small for the fabric in view of the increasing use of outside mooring. Personally, I have made a great many experiments on the exposure of fabric and other materials, particularly at the Goodyear plant. We have had exposure tests running constantly on all kinds of materials, including doped, rubberized and otherwise-coated fabrics.

It might be thought at first sight that the worst condition for fabric would be in the winter when storms rage, when alternate freezing and thawing occur and much moisture exists; but it is not. Almost any fabric will last through the winter, but I have never yet seen any airship fabric, no matter how well protected, that will last through one summer of continuous exposure. I do not wish, of course, to make any rash assumption, but from all the experience that I myself have had, or that I know specifically has been had by anyone else, including the Bureau of Standards and the Navy, I am forced to assume that the 4 and 5 years' service for an outer cover mentioned by Dr. Arnstein has been mainly service within the hangar.

Now coming to the benefits of metal, I do not wish to take unfair advantage of Dr. Arnstein, because some of his suggestions have been extremely good; but I took as rather a compliment to the Metalclad construction his remarks about the advisability of incorporating surfaces of metal in the present fabric, both the outer cover and the internal gas-cells. That apparently applies to durability and gas tightness, as well as to thermal effects and protection from static electricity. Accepting Dr. Arnstein's statement that, by incorporating metal with the fabric, the latter can be made to last almost as long as the pure metal, why not, indeed, go the whole way and get the full benefit of metal construction?

Since Dr. Arnstein refers to no actual tests of the fireproof quality of his new combination of fabric and metal, the matter must be regarded as merely one of opinion. Duralumin melts at 1200 deg. fahr. It would be interesting to know the temperature at which the fabric referred to would break down. If it is the layers of metal that produce the improvement, I again ask the question; "Why not go to a single metal layer of really substantial thickness?"

I grant Dr. Arnstein fully, completely and without reservation his statement that a fabric cover, properly stretched in place and kept in perfect condition, to all intents and purposes has no more skin friction than metal. Unfortunately, that is an ideal case which, in practice, has been very far from being an actuality. The fabric covering of the airships that we have in commission in this Country has given a great deal of trouble from becoming loose, under the varying atmospheric conditions, and not only producing troubles structurally with regard to the varying stresses but resulting in a great deal of actual flapping, which is extremely unfavorable in its effect on speed. The British have also had almost constant trouble in that respect. It is, of course, quite possible that no trouble of that kind has ever been had in Germany.

It has been customary for designers in this Country to ignore the strength properties of the fabric cover, except where it puts an unfavorable load on the frame. As Dr. Arnstein does not explain the "elaborate means in design and application" that make the fabric parts dependable as strength elements, the point is a hard one for me to discuss. Even allowing for such improvements as will enable the fabric to contribute part of its strength, why not use material that is known to be 100 per cent dependable in its structural properties?

The ratio of strength to weight, as quoted by Dr. Arnstein, apparently employs the elastic limit for duralumin and the ultimate breaking-strength on a quick pull for fabric. Actually, the metal will hold a load greatly in excess of its original elastic-limit for an indefinite time, whereas fabric on an average will not hold more than one-half its normal strength on a time test, that is, under continuous load. Any comparison of the strength of fabric and of metal is unfair unless we take fabric that has been plied up in such a way as to give practically uniform strength in tension and in shear in all directions, as does the metal. A proper comparison on this basis is given in the Appendix to my paper.[10]

It is not true that the metal skin must be "permanently under internal pressure," but only in proper proportion to the aerodynamic forces, provision for which is entirely automatic under all operating conditions. A severe

[9] See THE JOURNAL, June 1921, p. 595.

[10] See THE JOURNAL, February 1926, p. 125.

side gust on the ground is hard for any airship to handle without internal pressure; but why the objection to putting it into condition, by arbitrary means if necessary, the better to resist such forces? What it seems to boil down to is this: without internal pressure, the Zeppelin and the Metalclad ships may be made approximately equal in strength, but the latter has a great advantage in that it can withstand a very substantial pressure, if necessary.

As to the safety of fabric against tearing, the fact is known that the immediate cause of the Shenandoah's breaking-away from its mast was the tearing of the fabric on the upper fin. When the ship broke away, the fabric was not only torn immediately around the break in the bow, but a huge tear extended for approximately 35 ft. toward the rear.

Dr. Arnstein's remarks about the good electrical properties of "future metallized material" and the "useless added weight" produced by introducing more metal might be more conclusive if it were not for the fact that the Metalclad construction taken as a whole seems to be actually lighter for the same volume.

The "insulating-jacket space" in the Zeppelin is made a virtue only by having considerable air-ventilation through all parts of it. Unless Dr. Arnstein's tests in this connection are more complete than any I have seen, much remains to be done in the study of the effect of radiation on airships. Such tests of our own so far have been rather crude.

"The heavy coating of dope for protection against humidity" in the case of the metal amounts to not more than 0.005 lb. per sq. ft., which certainly is much less than that required to fill up the pores of the fabric, and, in spite of any amount of dope, moisture still seems to work into the fabric of a ship like the Los Angeles to the extent of thousands of pounds.

As to corrosion and vulnerability, it is true that duralumin does corrode to a certain extent, particularly in salt water. Our water model, entirely unprotected on the inside, was inflated with tap water off and on for a period of approximately 5 months. It corroded enough to cut down the strength appreciably, but the factor of safety was still higher than that of the Shenandoah at the end of that time.

The corrosion in the gas space, where there is no oxygen and very little moisture, would seem from all experience that has been had so far, to be at the most a very small quantity, especially as we are going on the safe side by putting a complete protective film over the inside, as well as the outside.

The question might then be asked: If it is necessary to protect the metal, why is metal better than similarly protected fabric? But we must go a great deal deeper than that. The principal deteriorating effect on fabric is not moisture but sunlight, and sunlight has absolutely no effect on metal. The improved type of dope put on the metal surface seems to last almost indefinitely and, by protecting the surface, prevents any and all corrosion that might take place underneath. If there is a bad scratch or, due to some combination of circumstances, local corrosion forms a weak spot that breaks through, it has been amply proved beyond the possibility of doubt that there is no chance of that break's spreading. We tested the water model in that respect under the most severe conditions, much more severe than the ship would ever be called upon to endure. A hole of any reasonable size and from whatever cause is absolutely local. There is practically no tendency whatever for it to spread.

The reason is contrary to what might ordinarily be supposed. The very stiffness and homogeneity of the metal seems to be assurance against further tearing. After a hole has been formed, the stresses, instead of being carried across it, are now carried around it without any "gapping" of the hole.

Dr. Arnstein's fear of the thin metal sheet does not fit in very well with his proposed use of much thinner metal layers in combination with cloth. Although the surface plating on our first small ship is admittedly of practically the minimum thickness, we should be only too glad to put it on test in competition with any fabric, or combination of fabric and metal, that has ever been devised.

It might be of passing interest to note that the slack partitions and internal corridors for strength, the methods of inspection and the like that have been mentioned by Dr. Arnstein as applying to the latest Zeppelin design were component parts of our first Metalclad design and have been retained, essentially the same, for the larger sizes outlined to date.

Inspection and repair is a matter that is almost a whole subject in itself. I would not impose upon you by going into that subject in detail. Suffice it to say that Dr. Arnstein's objections were very forceful and well put from the point of view of the methods and means employed for the repairing of fabric airships. We cannot properly repair a metal airship by slapping a patch on the outside, any more than a steel steamship can be repaired by sending down a man in a boatswain's chair to nail a piece of wood to the surface. We have, however, developed means of inspection and repair that seem to us, at least, as efficient and in some respects more so than those possible with the complicated and delicate structure that is involved in the Zeppelin type of ship.

The wording, "instant repairs," which Dr. Arnstein uses so frequently, would hardly apply even to a patch for which the cement must dry an appreciable length of time. As a temporary expedient, a similar patch can also be applied to the surface of the metal plating; but we have developed a better system of repair by means of which a hole of any reasonable size may be repaired from the outside in a time not to exceed 2 min.

As a counterpart to the "instant repairs" on the Zeppelin ship, we are told that great amounts of valuable helium "will flow away immediately from the slightest hole at a high rate of speed" from a metal container, and that, due to the internal pressure, it will take a long time for even temporary repairs to be made. As mentioned in the paper, the ship will not have to be under pressure except when under power. Unless the pressure is intentionally maintained, it would be relieved from its extreme maximum to zero by a loss of only 2000 cu. ft. of gas.

The small ship described will have no greater facility for repairs during flight than most other airships of similar size. For the larger ships, however, facilities may readily be provided for reaching one side of any part of the surface. In the case of an ordinary repair, it is not necessary to work from both sides any more than it is necessary to send a man into the interior of a Zeppelin gas-cell in order to patch a hole. To close this part of the discussion, it seems necessary only to suggest as a further question: May it not be an advantage to have a stronger, more substantial construction, standing in very little need of repair, even though in some cases repairs might be more difficult? The latter point, however, can be fully settled only by actual experience.

The question is raised as to how the airship can be deflated. This is simply the reverse process of the

method of inflation mentioned in the paper. It may be done in either a horizontal or a vertical position.

The purity of the gas should remain exceptionally high as, with metal, there seems to be practically no back diffusion of air into the gas, as is the case with all types of fabric. This advantage of the metal container should be specially effective in the proportion that air can be kept out of the ballonet.

I am not an authority on the subject of lightning. None of us here are, to any extent, so we must rely on those who have established a reputation along such lines. Prof. R. A. Millikan, of the University of California, has stated:

> It is my opinion that a metal airship unconnected with the earth by metallic conductors has so small a capacity that it will always assume essentially the potential of its surroundings and be free from danger of damage by lightning.

From the practical standpoint, another great authority on the subject of lightning is F. W. Peek, Jr., of the General Electric Co., who recently presented a paper[11] on that subject before the Franklin Institute, Philadelphia. Unfortunately, I was not able to reach him personally because he was out of town, but his associate, W. S. Moody, wired as follows:

> Peek at present on Pacific Coast. I agree with you that lightning not likely to damage metal airship, except possibly to produce small hole at point of direct contact. Even this highly improbable as the airship becomes highly charged before bolt strikes it.

Here is the Navy Department's view, as expressed by its aeronautical engineer, C. P. Burgess:

> There should be complete safety from lightning and static electricity.

There would seem to be some danger in the air-space between the two covers of an ordinary type airship. It is a very likely place, on preliminary analysis, for an explosive mixture to develop. On the other hand, with the single-envelope ship, having only a single metal fireproof cover, if any leakage does occur, the gas goes up and away, and there is no chance for its being confined and mixed with the air.

Bearing on this phase of the lightning question, I have a report of the Naval Aircraft Factory, where a great many valuable tests with static machines have been made. They were not made, of course, with so high a voltage as that of lightning, but the engineer in charge, J. B. Flowers, has made some interesting observations. I will read three of his conclusions:

(1) A high-voltage spark, similar to lightning, will pierce the outer cover of an airship, due to the fabric's having high resistance, and the cover will be enveloped in electric flame within the point struck and the nearest net wire on the gas cell, as it occurred in the laboratory experiment

(2) A cover, having an extremely low electrical resistance, such as aluminum foil cemented to fabric, is proposed as an almost absolute protection for an airship against lightning, as the aluminum metal acts as a conducting shield and prevents the lightning from entering the cover at any point. An airship so protected should escape damage, as the lightning would be conducted over the surface without breaking into flame, while on its way from cloud to earth

(3) Aluminum foil of extremely thin gage can be purchased and experiments could be tried to determine the proper gage-thickness of the metal which would conduct the lightning over the outer cover without breaking into flame. The proposed aluminum outer cover would weigh the same as the present outer cover

In other words, a rather feeble attempt is proposed to attain the electrical advantages of the full Metalclad ship by the use of an extremely thin foil on the outside, in a way somewhat similar to that suggested by Dr. Arnstein. It may be conceded that a Zeppelin with its metal framing and wires is almost 100 per cent safe against lightning, but why not make it safer still by a complete casing of metal?

My authority for the strength of the Shenandoah is given among the references in the Appendix to the paper.[12] The calculated factor of safety was based upon the results of thorough practical tests on the girders conducted at the Bureau of Standards. Not having Dr. Arnstein's calculations available, it is impossible to tell precisely where the source of difference with his figures lies.

He mentions a ship in the condition of rapid ascent. Possibly he is assuming the specified 6-deg. pitch as primarily relative to the ground rather than to the air, which would be the case during a rapid ascent in an otherwise balanced condition, the forces imposed in this case being much less severe than in the case actually assumed. Entirely aside from this, however, it is not at all surprising that engineers should differ to a considerable extent in their estimates of the help that can be obtained from such unreliable materials as fabric and cordage.

I have already stated the general basis of calculations used by the Navy engineers in the calculations of the Shenandoah factor of safety. It is stated further in the Shenandoah analysis that the effect of the longitudinal gas-pressure is almost exactly balanced in that ship by the tension in the gas-pressure wires, which answers another of Dr. Arnstein's questions. It is only fair to state, however, that I take no personal responsibility for these particular calculations on the Shenandoah, Dr. Arnstein's argument in this respect being entirely with the designers of that ship. The figures are well substantiated by the calculations of English designers; and, for what Dr. Arnstein calls the theoretical factor of safety, I cannot see that a figure of 2.00 is strikingly better than 1.68.

With regard to resistance, Dr. Arnstein is under one misconception. I think I have adequately stated in the paper itself the uncertainty of relying too minutely on the results of wind-tunnel tests of resistance, because of the great difference in the scale effect. The scale effect has not been included in the statement that I made in the paper as to the new shape, "less resistance for equal volume than that of the Shenandoah." The actual tests showed a resistance about 13 per cent less. The interference effect of the mounting was minimized by suspending the model from fine wires.

Taking the scale effect into account, according to the best methods known at the present time by the experts of the Navy Department, Bureau of Standards and National Advisory Committee for Aeronautics, the indications are that the resistance of the new shape will be approximately one-half that of the Shenandoah for full scale; but, again, I beg you not to take that as an actual fact until it has been proved in the full-scale condition. A supplementary check on it was made hydrodynamically by integrating the skin friction over the whole surface,

[11] See *Journal of the Franklin Institute*, February 1925, p. 141.
[12] See THE JOURNAL, February 1926, p. 130.

and this showed an almost exact agreement with the wind-tunnel results.

With regard to stability, it is true, as I have pointed out, that there is not very much inherent advantage, so far as stability is concerned, in the fat shape. The reason is simply one of detail. There is not the proper combination of hull and fins and, in particular, designers have tried to get the stability from the fins by using just the conventional four units around the hull, thereby letting most of the air go through between the fins without their acting upon it.

If Dr. Arnstein's doubts as to the stability of the short fat shape are based on the use of the conventional four-unit type of control surface, I must agree with him. It is the combination of the whole that counts, not picking out one particular feature and saying it alone is responsible. We cannot say that. But, as a whole, we have not only the theoretical results but have checked the results from two different wind-tunnels to prove amply the figures given. The dynamic effects have approximately been taken into account in calculations, but further tests are planned to check this particular item.

Incidentally, a very interesting test is being made at the present time, in the high-pressure tunnel at Langley Field by the National Advisory Committee for Aeronautics, that will probably throw further light on aerodynamic questions, particularly with respect to resistance and scale effect.

Dr. Arnstein's good wishes for the success of our undertaking are very much appreciated.

LIEUT-COL. C. DEF. CHANDLER[13]:—Although not mentioned in the paper by Mr. Upson, it is assumed that the metal gas-envelope will be attached to the outer edges of the structural frame at frequent intervals. If such attachment is by rivets, it would appear probable that the longitudinal stresses produced by very slight deformations in a structure having a length of several hundred feet would be sufficient to tear the thin metal of the envelope at the riveted points or at least to allow leakage of the gas.

I recall that, some years ago, engineers of the Zeppelin Company, in commenting on the safety of rigid airships inflated with hydrogen, stated that lightning had been known to strike an airship while in flight, without igniting the gas and without its being realized by the personnel inside the ship at the time, fused spots having been found on the duralumin frame that were supposed to be the points of the upper contact of the lightning discharges; also, that a hanging radio-antenna fused and dropped off entirely. The comment further called attention to the fact that the air-space between the outer cover and the gas cells served as a protection against ignition of the gas by lightning, because the hydrogen, in effect, was surrounded by a metallic shield of framework, the outer portion receiving the discharge being separated 1 ft. or more from the gas-containers.

Regarding the expectation that a discharge of lightning would make contact over a large area of the conducting surface of a Metalclad airship, instead of at a single spot, an observation of the discharge from any electrical source of high voltage, such as between the spark-gaps of a Leyden jar or the early spark-type radio-sets, indicates that, no matter how much metal surface is available, invariably the spark, or train of sparks, always enters the metal at a small point, without diffusing over the outer surface of the electrodes. With such simple examples available and frequently noted, the evidence does not appear to be sufficient for assuming that lightning passing into a Metalclad airship would act otherwise. If the lightning does make contact at a single point, as seems certain, the great heat, ordinarily evolved, may be expected to melt the thin envelope of metal and probably to ignite the hydrogen that is under pressure and in contact with the inner surface of the metal envelope.

If the hydrogen that issues from a small hole in the thin metal envelope becomes ignited by lightning or other cause, the heat of the hydrogen flame should be expected to melt the thin metal rapidly, thereby quickly enlarging the hole to dangerous dimensions, unless some means, not apparent to me, were available for limiting the size of the hole.

It is understood that, as the hydrogen becomes contaminated by the air that gradually leaks through the fabric ballonet, the purity will be increased by "purging" with pure hydrogen, in the manner that has been customary for non-rigid airships, allowing the impure hydrogen to escape as waste. It would be interesting to learn what method has been devised for removing all the gas from one compartment, whenever helium needs purification, such procedure being desirable, if helium should be used as the inflating gas, because of its greater initial cost.

MR. UPSON:—Colonel Chandler is correct in assuming that the frame members are riveted to the outer plating. The stress transmitted by the rivets, however, is extremely small; hence, they need not be very closely spaced. The effect of the rivet holes is allowed for in the strength calculations. As mentioned in the paper, the deflection of the ship, as a whole, must be held within very narrow limits. Actually, it will be very much less than any airship hitherto built. In the larger ships means may be provided for deflating and inflating one compartment at a time by the same method that has been described for the small ship as a whole.

W. F. G. SWANN[14]:—The following are matters that seem to me to be pertinent in relation to the possibility of a metallic airship's being struck by lightning. The electrical capacity of a body is of the order of magnitude of its linear dimensions. In particular, the capacity of a prolate spheroid of semi-major axis a and semi-diameter of cross-section b is

$$C = 2ae/\log_e [(1+e)/(1-e)]$$

where e is the eccentricity of the ellipsoid and is given by

$$e^2 = 1 - b^2/a^2$$

For an airship 100 m. long and 33 m. in diameter at the maximum cross-section, the capacity is about 3000 coulombs.

Estimates of the potential of a thunder-cloud give it as about 10^8 volts[15] or about 10^9 volts.[16]

Taking the lower figure, we find that, if the airship should receive a discharge which would raise it to the potential of the cloud, it would receive about 0.3 coulomb. For discharge from a cloud at 10^8 volts to earth, Peek[17] gives the maximum current as 78,000 amp. Humphreys[18] estimates currents of the order 10^5 amp. for lightning flashes. Suppose we consider a case where the current from the flash enters the airship over an area

(*Concluded on p. 421*)

[13] Formerly chief of the balloon and airship division, Army Air Service, City of Washington.

[14] Director of Sloane Laboratory, Yale University, New Haven, Conn.

[15] See *Journal of the Franklin Institute*, February 1925, p. 147.

[16] See *Philosophical Transactions of the Royal Society of London*, vol. 221, p. 103.

[17] See *Journal of the Franklin Institute*, February 1925, p. 147.

[18] See Physics of the Air, p. 399.

Fitting the Machine-Tool to the Job

By O. C. KAVLE[1]

PRODUCTION MEETING PAPER *Illustrated with* PHOTOGRAPHS AND DRAWINGS

ABSTRACT

THE importance of analyzing operations to be performed on a given production job; determining how it can be done best, most quickly and most economically; and adapting standard machines; or designing and building special machines for doing the work does not seem to be generally appreciated. Such preliminary work often results in large savings of time in production work, of floor space occupied by the machinery, of scrap losses, and usually in improvement of the quality of the work performed. If it is necessary to develop a new machine for a given purpose the savings effected will often pay for the machine in the first year of its use. The customer should pay all the cost of this development work because very often the special machine is suitable for use by only one customer and on only one production piece and the machine-tool designer and builder cannot recover any losses by building and selling duplicate machines.

The tendency in many cases has been for manufacturers to buy large complicated machines to perform operations that can be done on much simpler units, because the machines have been stock products, but the automobile industry is believed to have reached a stage where the production manager can consider more simplified production. Smaller and simpler machines effect a saving in power required to drive them and also occupy so much less floor-space that they may save the expense of erecting additional factory buildings. An example is given of a machine for boring and bottoming air-cooled-engine cylinders that equals the production of four machines of equal size which it has displaced. One of the main features of this machine is that it permits the loading of cylinders into the machine while the tools are doing their work on other cylinders.

This saving of handling time is exemplified in various other machine-tools that are described and is emphasized because, if the handling of the material can be timed with the machining operations, it may mean that the cutting speed can be slowed-down, thereby effecting a saving of tool wear, or the handling can be speeded-up to keep pace with the cutting speed. The important object with all production work is to keep the tools constantly producing chips.

Cylinder-drilling operations that required 13 min. and resulted in a loss of from 25 to 30 per cent of cylinder castings were reduced to 3 min. and a scrap loss of less than 2 per cent by rearranging the locating points for the drilling operation.

Other machine-tools adapted or designed for doing specific jobs include one for finishing the intake and exhaust ports in air-cooled cylinders, one for boring the large and small ends of connecting-rods, one for parting the big ends and making the cut in the small ends at the rate of 500 to 600 rods per day, a small machine for the centrifugal casting of babbitts in connecting-rods, a simple little machine for machining the crankshaft and camshaft bearings in crankcases, another for boring holes simultaneously in opposite ends of crankcases, one for machining transmission cases, a machine that drills holes diagonally in crankshafts and saves a large loss in broken drills, a standard multiple-drill adapted for drilling holes in four directions simultaneously, a drill-press converted into a milling-machine for simultaneously finishing four bosses on different sides of the inside of a small metal case which formerly were finished by back-counterboring, and a cylinder hone with spring-backed and adjustable abrasive stones.

Lapping of engine cylinders and other plain-bearing surfaces more than repays for the time spent on the operation; failure to lap the surfaces causes many of the shortcomings that are common in many engines, but it is a mistake to think that errors in any machining process can be corrected by lapping. Any imagined danger of charging the bearing surface with particles of emery can be avoided merely by using the proper lap-material and employing a hardwood lap for the final finish.

BY the title of this paper I mean analyzing the work or operations to be performed on a given production job, determining how it can be done best, most quickly and most economically, and adapting or designing and building a machine for doing the work. I feel that the importance of doing this preliminary work is not generally appreciated. It often results in great savings of time in production work, of floor space occupied by the machinery, and consequently of money, and usually in improvement of the quality of the work. As production increases in volume the quality of the article produced improves, because with larger production more money is available to devote to bettering the methods

FIG. 1—MACHINE FOR BORING SINGLE ENGINE-CYLINDERS

This Carries Three Sets of Boring-Tools and Two Sets of Bottoming-Tools and the Work-Holding Turret Has Five Machining Positions and One Loading Position. A Finished Cylinder Is Taken Off and Replaced by a Cylinder To Be Bored While the Boring and Bottoming Are Proceeding on the Five Other Cylinders

[1] Senior partner, Manufacturers' Consulting Engineers, Syracuse, N. Y.

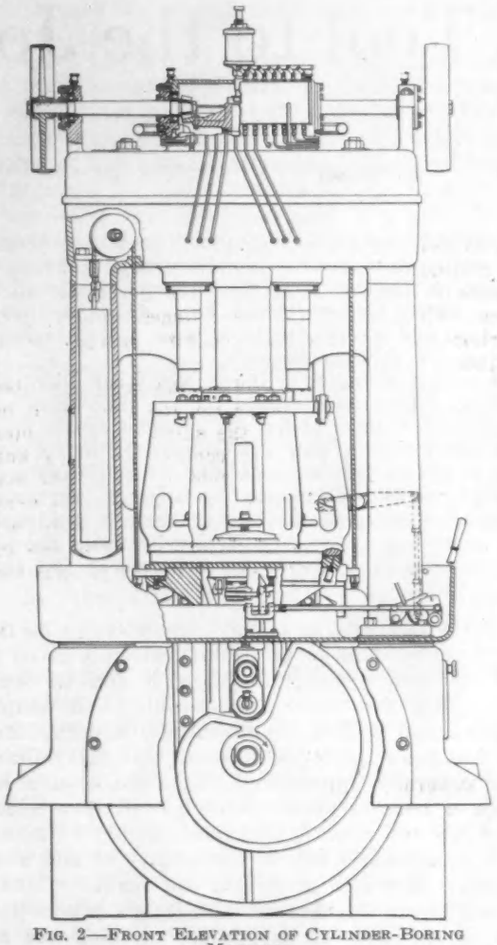


FIG. 2—FRONT ELEVATION OF CYLINDER-BORING MACHINE

The Large Feed-Controlling Cam at the Base Has an Extremely Quick Drop and Quick Approach. The Large Portion of the Cam Feeds the Work Rather Rapidly to the Boring-Cutters and the Last Portion Holds the Work during the Machining of the Bottoms of the Cylinders. A Dwell at the Extreme Top of the Cam Allows the Tool To Give a Smooth Finish-Cut

and to the building of better machines for doing the work.

I shall present some typical examples of methods and of adapted and special machine-tools that have speeded-up production and saved handling time and floor space, with the hope that from some of them a few ideas, at least, will be gained by others that may be of value, and to illustrate the desirability of devoting some study to the subject and using for each job the kind of machine best suited for the operations required. If it is necessary to develop a new machine for the purpose, the savings effected by it will very often pay for the special machine in the first year of use.

Unfortunately, the manufacturers in the automotive industry are, in general, unwilling to pay the necessary costs of developing special machines, notwithstanding the savings they produce, and do not always seem to realize that any machine-tool builder, in developing such a machine may not always get it exactly right at first. In such a case they are too prone to think that he has failed and to go to some other machine-tool builder with the problem, perhaps only to have another failure, whereas the first builder, by reason of his first failure, is in better position to build the machine right the second time and at less cost. Some allowance should be made for human fallibility and it should be recognized that in any new endeavor success is not always possible at the first attempt. Every manufacturer who has produced a new engine or chassis in his own plant must realize this.

Someone must, of course, pay for the development work on machine-tools. The cost of duplicating the perfected machine does not represent its true cost, and the builder is not able to stand the difference. If every such machine-tool could become a standard machine that would be in reasonably large demand, the builder might recover his losses on the first one, but very often the special machine is suitable for use by only a single customer and on only one production piece. Therefore the customer should pay all the costs of developing it and enough more to allow the builder to realize a reasonable profit that would enable him to stay in business and be available for future work of a similar nature. To avoid any misconception in this connection, it may be advisable to state that my firm is not interested financially in the manufacture and sale of machine-tools.

We believe that the automobile industry has come to that stage in its production where the radical changing of design is becoming less and less each year and the production manager can consider more simplified production in his plant. The tendency in a great many cases has been to buy large complicated machines to perform operations that could be done on much simpler units,

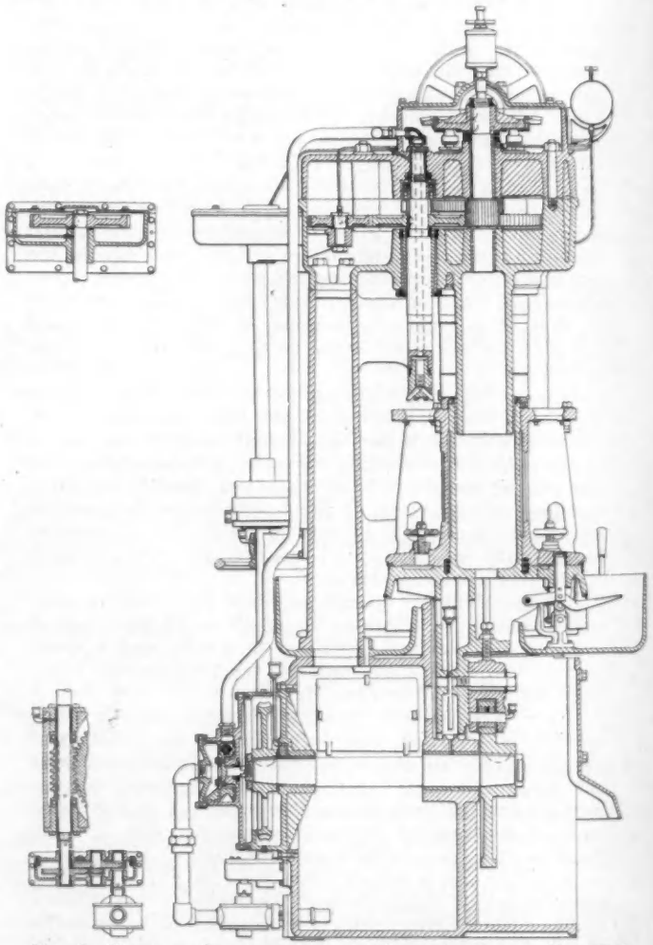


FIG. 3—VERTICAL SECTION THROUGH CYLINDER-BORING MACHINE

In the Base Is a Water Reservoir from Which Water Is Pumped through a Line at the Left to the Top, Where a Registering Valve Opens and Closes at Predetermined Cycles of the Machine. The Water Is Forced Down through the Spindles and Thrown against the Walls of the Cylinders To Wash Out the Chips. The Flow Is Shut Off until the Tools Enter the Cylinders Far Enough So That the Operator Will Not Be Annoyed by the Water-Flow

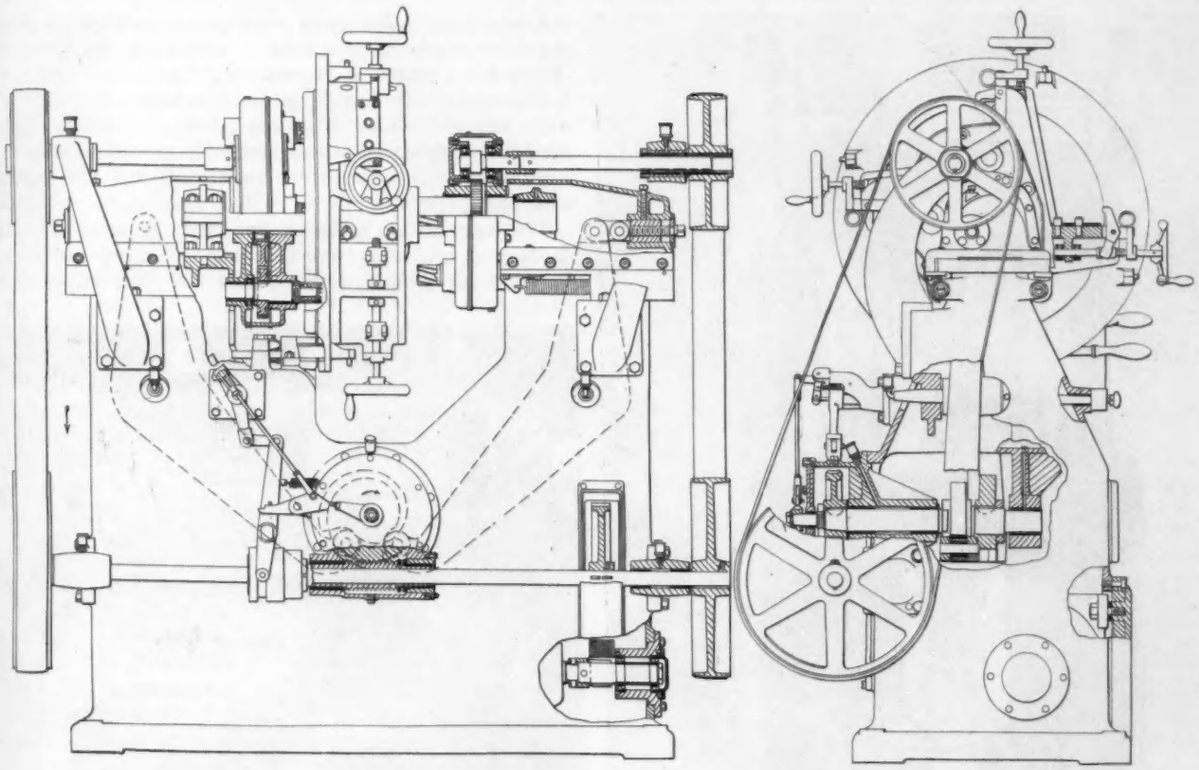


FIG. 4—FRONT AND SIDE ELEVATIONS OF MACHINE FOR FINISHING INTAKE AND EXHAUST PORTS
Four Work-Holding Positions of the Turret Provide for Three Machining Operations and One Loading Operation, Thereby Eliminating Handling Time. No Stock Machine Could Be Obtained To Perform These Operations on the Cylinders Properly

because the machines have been stock products. The use of smaller and simpler machines not only effects a saving in power required to drive them but may also save floor space to such an extent in some cases that it may mean avoiding the expense of erecting new factory buildings. I hope to be able to show some concrete examples of these savings by a number of special machines.

MACHINE FOR MACHINING ENGINE CYLINDERS

The first of these is a machine for machining single air-cooled-engine cylinders, as shown in Fig. 1. This may not show a simplified method of doing the work but it has resulted in a material saving of floor space, because this machine equals the production of four machines which it has replaced and each of which occupied as much floor space as the one shown. This machine is used for boring and bottoming the cylinders and has three sets of boring-tools and two sets of bottoming-tools. It machines the cast-iron cylinders in water, which takes the place of an air-blast that formerly was used to blow the chips out from the cylinder. The air-blast was used so much that the expense for compressed air became a vital factor.

One of the main features of the machine is the construction that permits the loading of cylinders into it while the tools are doing their work on other cylinders. Thus no time is lost in handling the material and the only time lost from actual boring is about 10 sec. per cylinder, which is consumed in the indexing operation. The work-holding turret has five machining positions and one loading position, and as the turret rotates a finished cylinder is taken off and replaced by a cylinder to be machined while the boring and bottoming operations are proceeding on the five other cylinders. In this way, one cylinder is finished completely in each cycle of the machine.

Of particular interest in the front elevation of the machine in Fig. 2 is the formation of the large feed-controlling cam, which has an extremely quick drop and quick approach. A large portion of the cam has a somewhat quick rise that feeds the work to the cutters, and the last portion of this holds the work during the machining of the cylinder bottoms. The extreme top is left with a dwell for the tool to give a smooth finish-cut. This can be done very easily with a cam and makes a simple and efficient feed.

Another peculiar feature is revealed in the cross-section through the center of the machine, Fig. 3. This is the fluid line at the left that carries water from the base of the machine to a registering-valve at the top that opens and closes at predetermined cycles of the machine, forcing the water down through the spindles and throwing it against the cylinder-walls. When the machine is in the position shown, the water is shut off and does not start flowing again until the tools have entered the work sufficiently far that the operator will not be annoyed by the water-flow. The water then continues flowing until the machining operation is complete but is shut off again when the tools start to back out of the work.

The particular construction of the boring-spindles is also worthy of note. They are mounted in plain bearings at each end and carry a set of radial ball-bearings that take the driving load close to the gear and have a ball thrust-bearing mounted at the upper end to take the spindle thrust-load. This arrangement was considered advisable to take the driving load off of the plain bearings to allow them to serve merely for steadying the spindle and in this way secure better work and longer life of the machine.

The relieving of the turret load from the bed so that the turret can be rotated easily is another interesting feature of the design. Its ball-bearings are mounted on

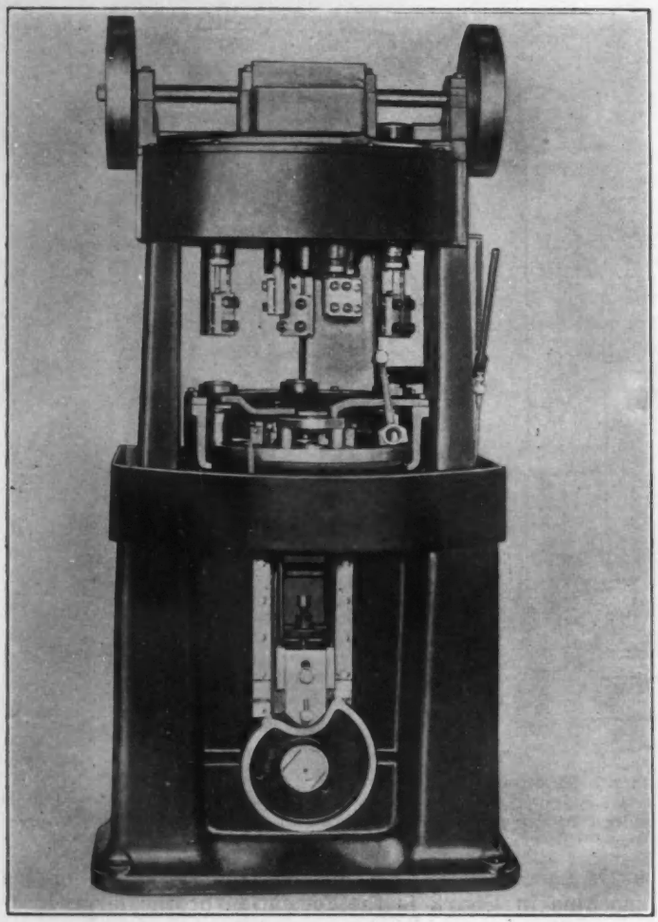


FIG. 5—MACHINE FOR BORING CONNECTING-ROD ENDS
Unfinished Rods Are Indexed and Loaded in One Position of the Turret While Three Sets of Tools Are Roughing, Semi-Finishing and Finishing Rods in the Three Other Positions. Tools Are Clamped into the Machine by Plates Held by Screws, Thus Facilitating Removal and Replacement of the Tools

springs that have been selected carefully so that the turret will represent a load of only from 50 to 100 lb. on the seat on which it is rotated.

This machine has been in operation and doing good work for a number of years. One completely machined cylinder can be produced with it in less than 2 min., whereas the time required originally for the operations was about 10 min.

We were called upon at one time to analyze cylinder-drilling operations that required 13 min. and that produced a scrap loss of from 25 to 30 per cent which was

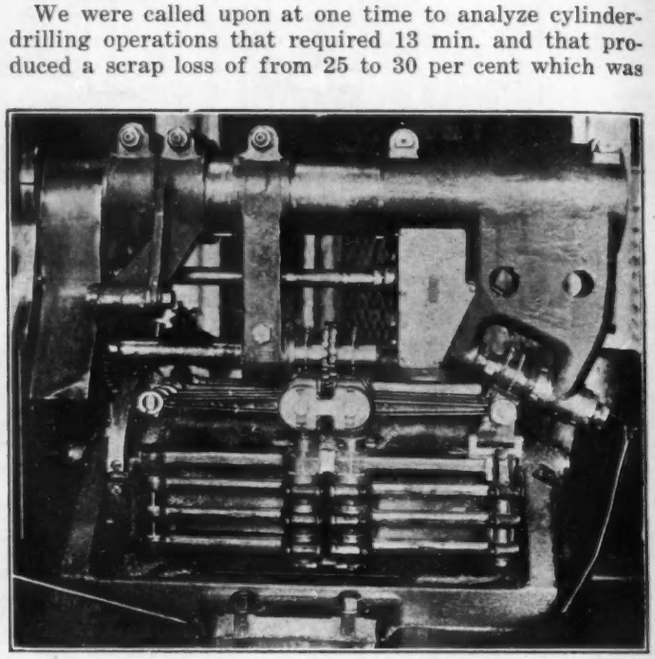


FIG. 6—CONNECTING-ROD BIG-END PARTING MACHINE
While the Tools at the Center Are Parting the Big Ends of the Six Rods at the Top of the Fixture and Cutters at the Right Are Making the Angle-Cut on the Small Ends, the Operator Removes the Three Rods on the Left End of the Fixture, Transfers Them to the Right-Hand Side and Puts on Three Fresh Rods at the Left. In This Way Three Finished Rods Are Produced for Each Cycle of the Machine. One Operator Can Part and Cut from 500 to 600 Connecting-Rods per Day

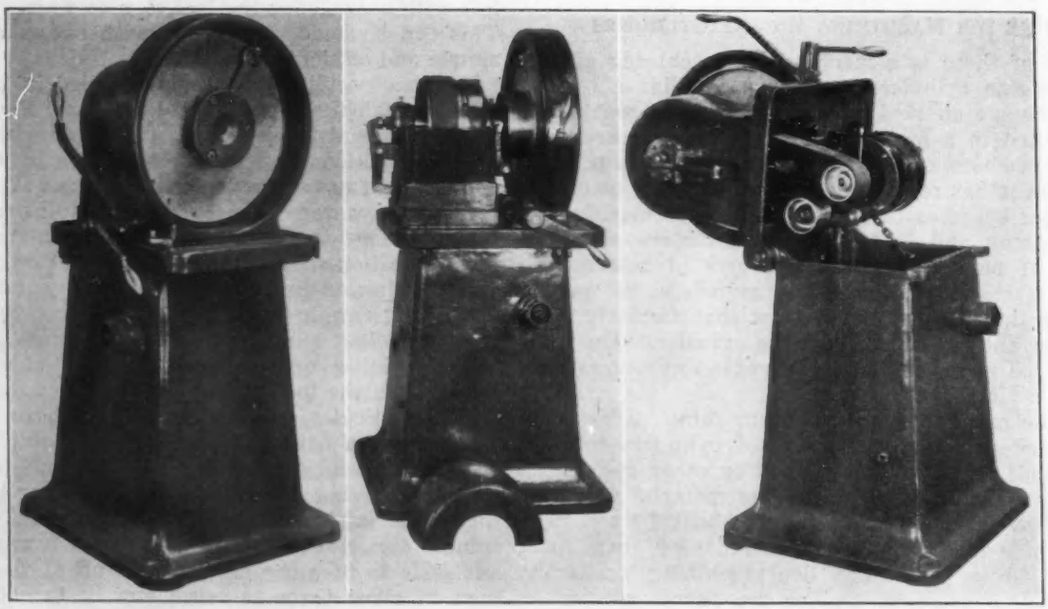


FIG. 7—NOVEL MACHINE FOR THE CENTRIFUGAL CASTING OF BABBITTS IN CONNECTING-RODS
A Connecting-Rod To Be Babbitted Is Secured in Position on the Aluminum Faceplate as Shown in the View at the Left, and a Measured Quantity of Melted Babbitt-Metal Is Poured from a Ladle into the Big-End at the Center. The Faceplate and Connecting-Rod Are Then Rotated Rapidly While the Metal Solidifies. In the Center View the Machine is Shown with the Cover Removed To Expose the Operating Mechanism, Which Includes a Cast-Iron Clutch-Pulley and Brake-Drum for Quick Starting and Stopping. Accessibility of the 1-Hp. Motor, Which Runs Continuously, Is Shown at the Right

called a foundry loss because of the inability of foundries to make all castings alike. We regard it as the production engineer's problem to save all the castings he can, regardless of slight discrepancies the foundry is likely to make. In the instance mentioned, by rearranging the locating points for the drilling operation, the scrap loss was reduced to less than 2 per cent and the average time for the operations per cylinder was reduced by 10 min.

On another occasion we were called upon to find the cause of a scrap loss that ran to from 40 to 50 per cent due to spoiled block-castings for six-cylinder engines. A study of the operation showed that the trouble arose in the first machining operation, which was the milling of the base and ends, as the cut was not being made square to the outside of the cylinder. Correction of this not only increased the production but improved the quality of the whole cylinder-block.

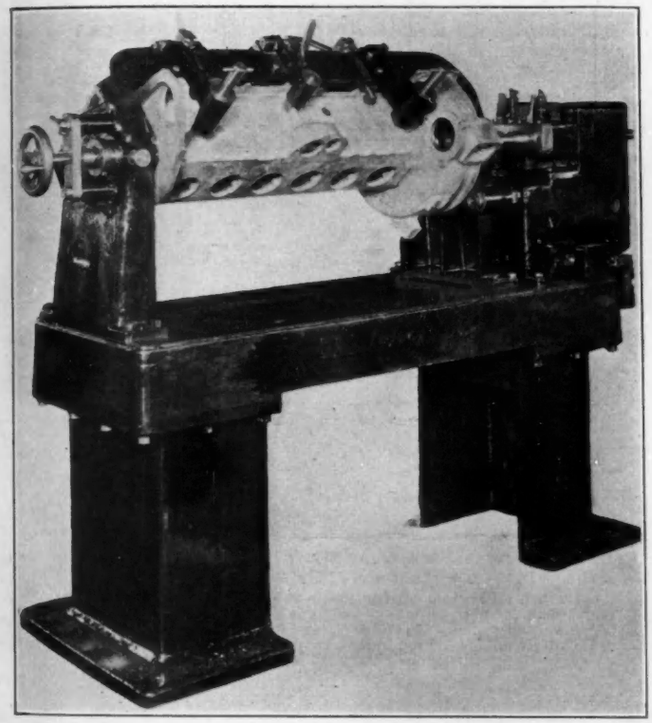


FIG. 8—SIMPLE MACHINE FOR MACHINING CRANKSHAFT AND CAMSHAFT BEARINGS IN CRANKCASES

This Is Noteworthy for the Small Floor-Space Occupied and the Way in Which the Crankcase Is Mounted, with the Fixture above the Work To Enable the Operator To Observe the Operation of the Tools. At the Right a Self-Contained Driving-Unit Drives and Feeds the Boring-Bar at Predetermined Rates

A similar machining operation, but of much less magnitude, on the intake and exhaust ports of the cylinder is performed by the machine shown in Fig. 4. This is also an example of the elimination of handling time. The machine has four holding positions of the turret, which provide for three machining operations and one loading operation. Rough, semi-finish and finish-tools are used. The machine is of unusual design for cylinder work and was so designed because no machine of a stock nature could be obtained to do this job properly.

The elimination of handling time whenever possible is emphasized because, if the handling of the material can be timed with the machining operations it may mean that the cutting-speed can be slowed-down to meet the handling time and thereby effect a saving of tool wear or the handling of the work can be speeded-up to keep pace with the cutting speed. The important object with all

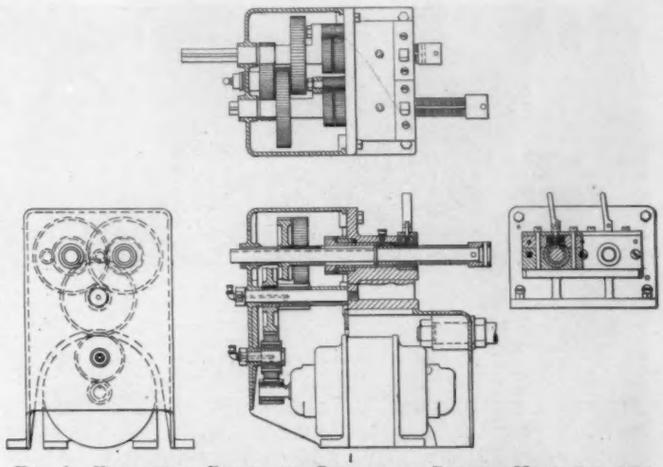


FIG. 9—ELEVATION, PLAN AND SECTION OF DRIVING-HEAD FOR THE MACHINE SHOWN IN FIG. 8

This Unit, with Self-Contained Electric Driving-Motor, Can Be Replaced with an Extra Driving-Head Kept in Stock, and Necessary Repairs Can Then Be Made to the First Unit Without Suspending the Production Operation of the Machine

production tools is to keep the cutting-tools constantly producing chips. Whenever the tools are not making chips they are not producing. It is not possible in all production work, of course, to keep the cutting-tools at work all the time, but that is the main point that we have in mind when making an analysis of any production problem.

ROTATING CONNECTING-ROD BORING-MACHINE

In the machine for boring the large and small ends of connecting-rods, seen in Fig. 5, the principle of indexing the work and loading while machining is illustrated again. Three sets of tools are used in the operations and there are four positions, one each for loading, roughing, semi-finishing, and finishing. The high-speed shaft-pulleys all run on ball-bearings. This machine has been

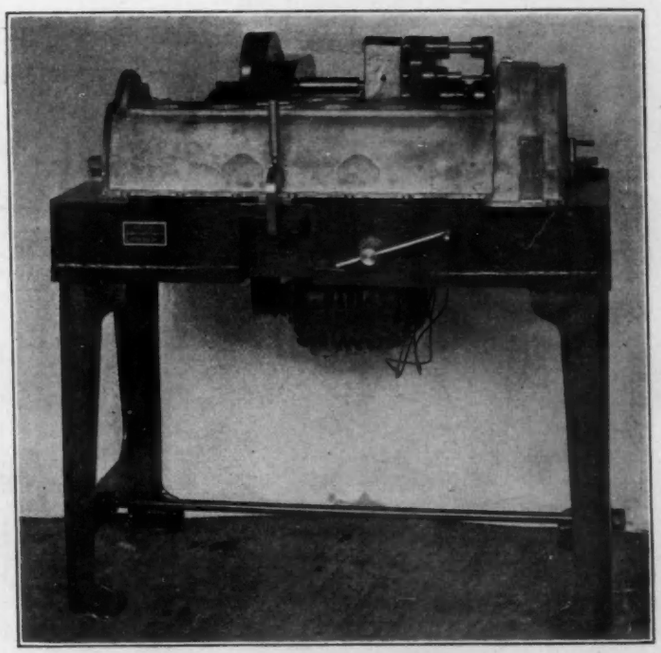


FIG. 10—MACHINE FOR BORING HOLES SIMULTANEOUSLY IN OPPOSITE ENDS OF CRANKCASES

This Simple Little Self-Contained Machine Bores the Holes for Attaching the Self-Starter and the Generator. The Crankcase Is Shown in Position for the Operations and the Driving Motor Is Seen Below at the Center

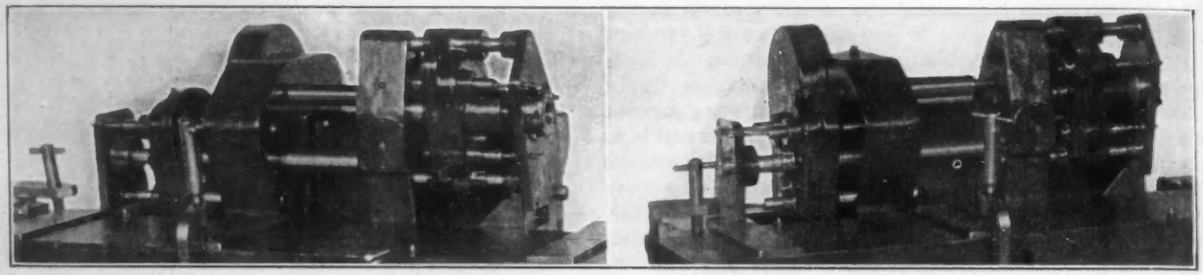


FIG. 11—VIEWS SHOWING TOOLS OF CRANKCASE-BORING MACHINE
In the View at the Left the Heavy Bar at the Center Carries a Tool for Roughing and Finishing the Large Hole for the Engine-Starter, and the Small Tools Above and Below Drill the Small Holes. In the View at the Right Tools for Boring Holes for the Generator in the Opposite End of the Crankcase Are Seen at the Left of the Machine

producing more than 300 finished rods per day and the work is easily held to satisfactory limits. It has been in use since 1916, with very low upkeep-expense. All of the tools are clamped into the machine by plates having four screws. This arrangement facilitates removal of the tools without extra lowering of the table.

A method used for parting the big ends of the rods since 1916 is shown in Fig. 6. While the rods are being loaded into the fixture, the tools are parting the rods at the middle of the big bore and also making the angle-cut at the end. While the rods are being cut, the operator loosens the nut on the holding-stud at the left, takes off the three rods on it, places them on the stud at the right, and puts on three new rods at the left to be cut. Three finished rods are produced in this way for each cycle of the machine. By this method one operator has been able to part and cut the ends of between 500 and 600 connecting-rods per day.

We have been cold-pressing forged connecting-rods to size instead of milling them. This gives a good surface and, to assure absolute accuracy on the surfaces at the big and small ends, we have been doing a very slight grinding operation. This method produces a high-class finish at very low production-cost. The most serious

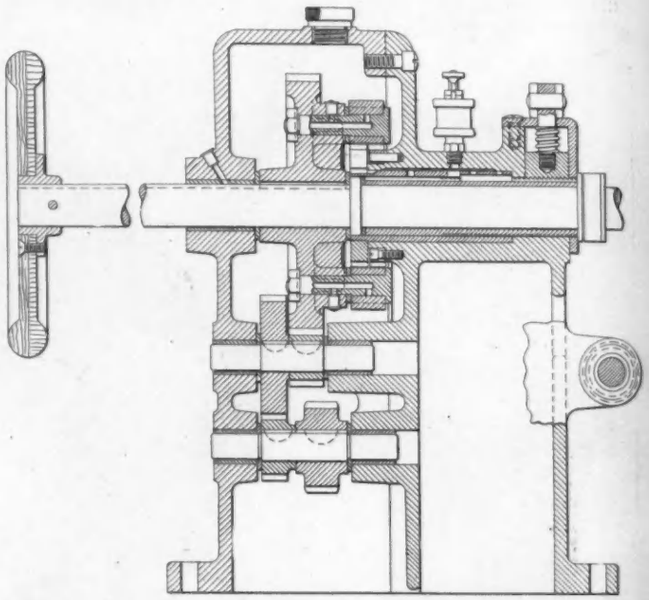


FIG. 13—VERTICAL SECTION AND END ELEVATION OF DRIVING-HEAD OF TRANSMISSION-CASE BORING-MACHINE
Drive from an Electric Motor Is by Silent Chain and Gearing. The Driving Shaft Carries Screw-Thread Bushings That Rotate at Predetermined Speed To Give Correct Feed to the Cutting Tools. The Head Can Be Attached to Any Simple Base upon Which Any Suitable Fixture Can Be Mounted

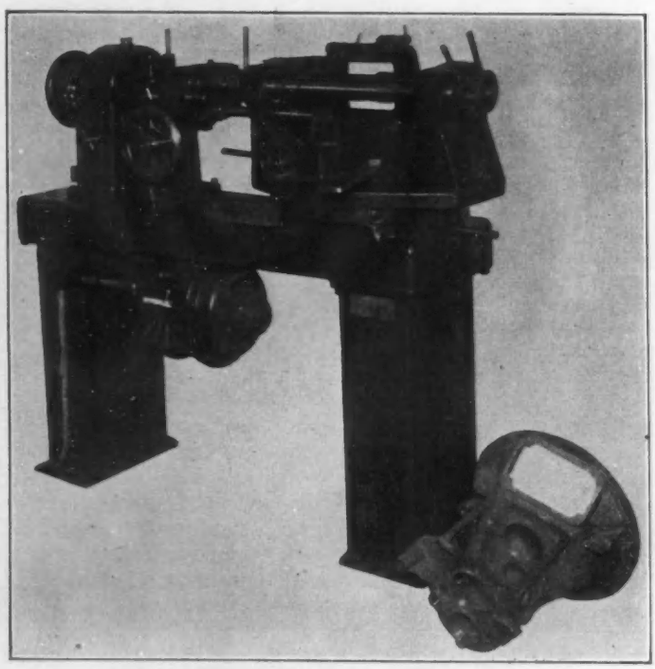


FIG. 12—MACHINE FOR FINISH-BORING TRANSMISSION CASES
The Unit Driving-Head at the Left Drives and Feeds All Bars and the Rotatable Fixture at the Right Facilitates Removing and Replacing the Bars in the Work

trouble that has been experienced with the cold-pressing has been in getting the forge shops to hold sizes within close enough limits to prevent putting too much stress on the cold-pressing tool. This difficulty was more pronounced during the war; I believe they can hold the sizes satisfactorily at this time. A great deal of the cold-pressed work can be held to much greater accuracy than can be done by milling-machine methods.

CENTRIFUGAL CASTING OF CONNECTING-ROD BABBITTS

A novel machine for the centrifugal casting of babbitts in connecting-rods is illustrated in Fig. 7. At the left the machine is shown with a connecting-rod in position against the faceplate. Babbitt is poured into the big end with an ordinary ladle that carries a measured quantity of the melted metal. The faceplate and connecting-rod rotate rapidly until the babbitt cools sufficiently to solidify. The operating mechanism can be seen in the central view, in which the cover of the machine is removed to expose the cast-iron clutch-pulley and brake-drums, the large diameter of which gives quick starting and stopping for inspection and removal of the connecting-rod. The clutch and brake are operated by the upper lever. The loading fixture is opened and

closed by the lower lever and is held closed by springs while the babbitt is being poured and is cooling.

The ready accessibility of the built-in 1-hp. motor will be observed in the illustration at the right. The motor runs continuously and takes care of the rapid and frequent starting of the clutch, spindle and faceplate. The faceplate is made of aluminum to reduce the weight of the revolving parts, which can be turned easily by hand to bring the connecting-rod into convenient position for removal.

Machining Crankcases by Grinding Recommended

The machining of crankcases, especially aluminum castings, by the grinding operation is recommended wherever it is possible in preference to the milling operation. This is because the crankcase, as prepared for the grinding operation, can be from 3 to 4 lb. lighter than the same crankcase as prepared for the milling-machine, due to the fact that any cutter with which a crankcase

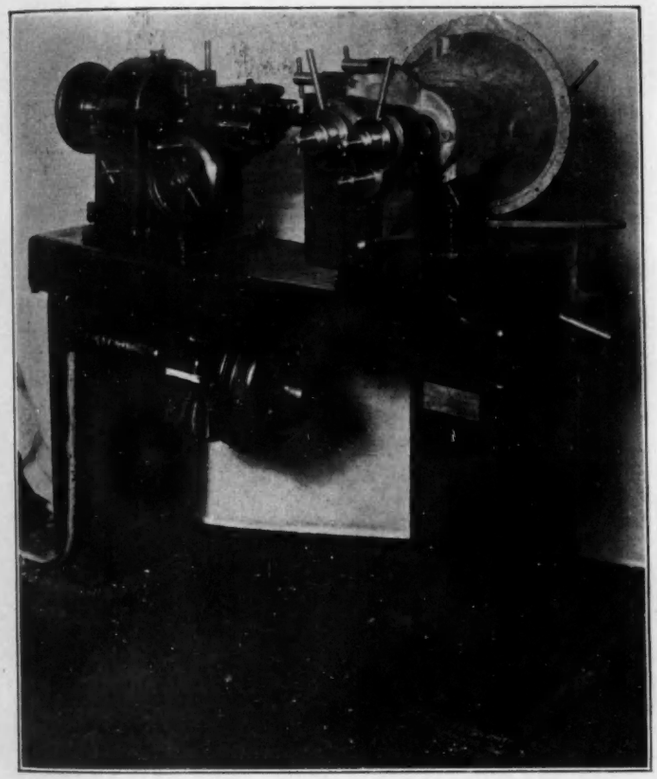


Fig. 14—Transmission-Case Boring-Machine with Fixture Rotated for Loading

A Transmission Case Is Shown in the Fixture Ready To Be Rotated into Line with the Driving-Head

can be machined must go under the scale to avoid the sand and other abrasive left on the outside, which is sure to ruin the cutting edge of the tools. The extra aluminum has to be paid for at a certain price per pound and it costs about one-tenth as much to remove this extra stock as is paid for the excessive weight.

A simplified machine for machining the crankshaft and camshaft bearings in crankcases is shown in Fig. 8. It is especially noteworthy for the small amount of space it occupies on the floor. The crankcase is mounted differently for machining than in any other machine of which I know, with the fixture above the work to enable the operator to see the operation of the tools. This has worked out very satisfactorily and also provides a quick way of loading the work into the machine. At the right

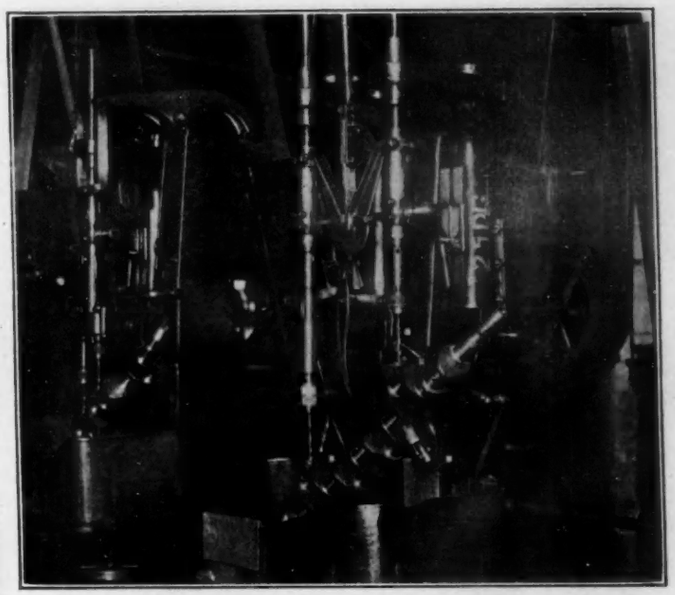


Fig. 15—Pair of Crankshaft Oil-Hole Drilling-Machines These Are Used in a Set of Three, Each of Which Drills a Pair of Diagonal Oil-Holes through the Cheeks and Main Bearings. The Three Machines Drill in Three Different Directions. One Operator on the Three Machines Does the Work on as Many as 50 Crankshafts per Day. To Obviate the Breakage of Drills in the Work a Special Cam Repeatedly Withdraws the Drills and Returns Them into the Work After a Stream of Oil Has Freed Them of Chips

side is a self-contained driving unit that drives and feeds the boring-bar at the predetermined rate. A sectional view of this driving head with the motor mounted in it is shown in Fig. 9. An extra driving-head can be carried in stock to exchange with one in use at any time when it becomes necessary, so that the machine can be kept in actual production operation nearly 100 per cent of the time. The replaced unit can then be repaired while the other is working. It is very desirable, when

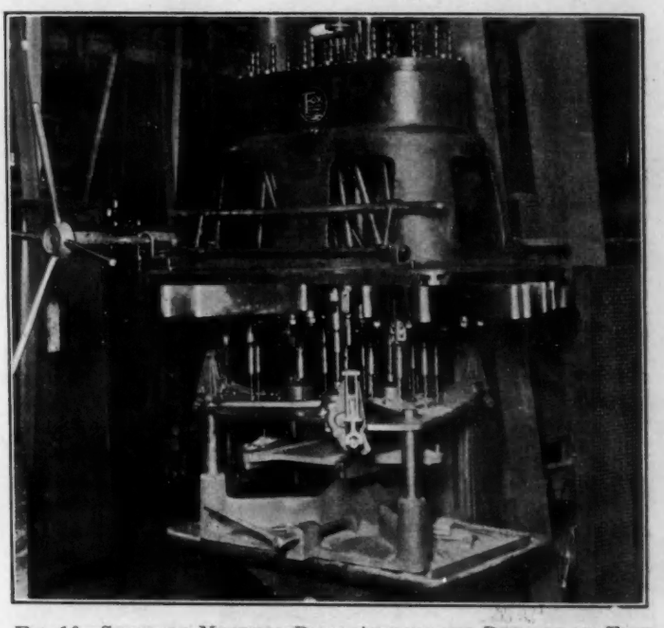


Fig. 16—Standard Multiple-Drill Adapted for Drilling in Four Directions Simultaneously

Three Horizontal Spindles Are Built into the Drill-Jig and Each Is Driven by a Set of Bevel-Gears from One of the Vertical Spindles. Bell-Cranks Feed the Horizontal Drills toward the Center of the Jig. Three Horizontal Holes Are Drilled 120 Deg. Apart While 15 or 20 Vertical Holes Are Being Drilled. The Casting Weighs 36 Lb. and Can Be Handled, Jigged and Drilled Four Ways in 45 Sec.

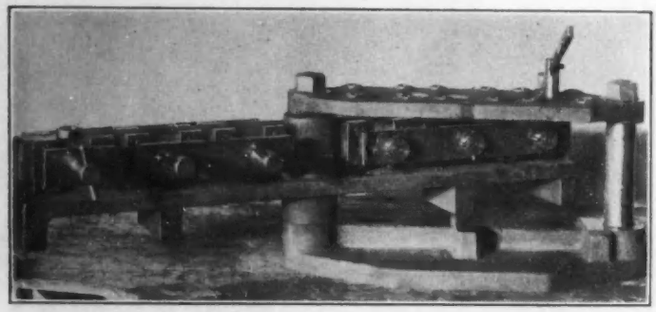


FIG. 17—ROTATING FIXTURE FOR LOADING WHILE DRILLING

designing equipment, to arrange for making such repairs as will be required from time to time without keeping the machine out of production.

A similar machine that carries a single bar is used for finishing the crankshaft bearings. This has also been in use for a number of years and is considered very desirable for this kind of work. Those who are familiar with the finishing of crankshaft bearings in crankcases will appreciate what the difference must be in the cost and upkeep of a tool of this size as compared with other machines commonly used for the purpose. The machine can be built just as sturdy and rigid as any for this class of work.

Fig. 10 shows a self-contained machine designed for boring holes simultaneously in the opposite ends of a crankcase for locating and attaching the engine starter and attaching the generator. The crankcase is shown in position on the machine. The tools for boring the starter end are seen in the right of the machine at the left in Fig. 11, in which the crankcase is removed. The

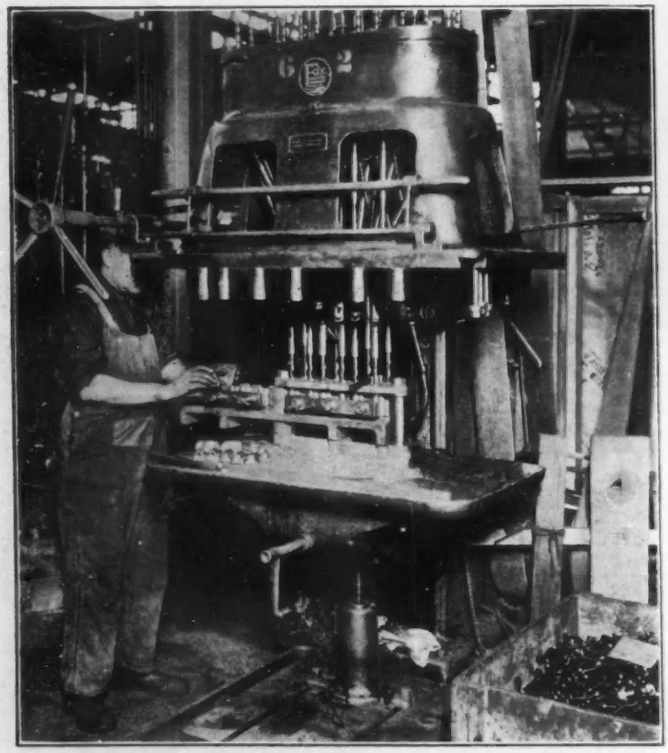


FIG. 18—ROTATING FIXTURE IN USE IN DRILLING MACHINE

The Operator Is Loading Pieces To Be Drilled in One End of the Jig While Holes Are Being Drilled by the Machine in Pieces in the Other End. When the Drilling Is Finished the Jig Is Swung Around and the Operations Are Repeated. With This Machine and Fixture It Is Possible To Drill Holes ½ In. in Diameter and 1½ In. Deep in 20 Pieces per Minute

large heavy bar in the center carries a tool for roughing and finishing the large hole while the small tools are drilling the small holes. Tools for boring the holes in the generator end are seen at the left of the machine in the other portion of the illustration.

MACHINING OF TRANSMISSION CASES

The machining of transmission cases calls for a number of interesting operations and we have designed some special features in a machine for the finish-boring operation on the main holes. This machine, complete with the bars in place, is shown in Fig. 12, while Fig. 13 is a section and end elevation of the driving-head unit that drives and feeds all the bars. This head is driven by the motor through a silent chain and gearing, with back-gear reduction to drive the shaft at proper speed. The driving shaft carries screw-thread bushings that rotate at the predetermined speed to give the correct feed to

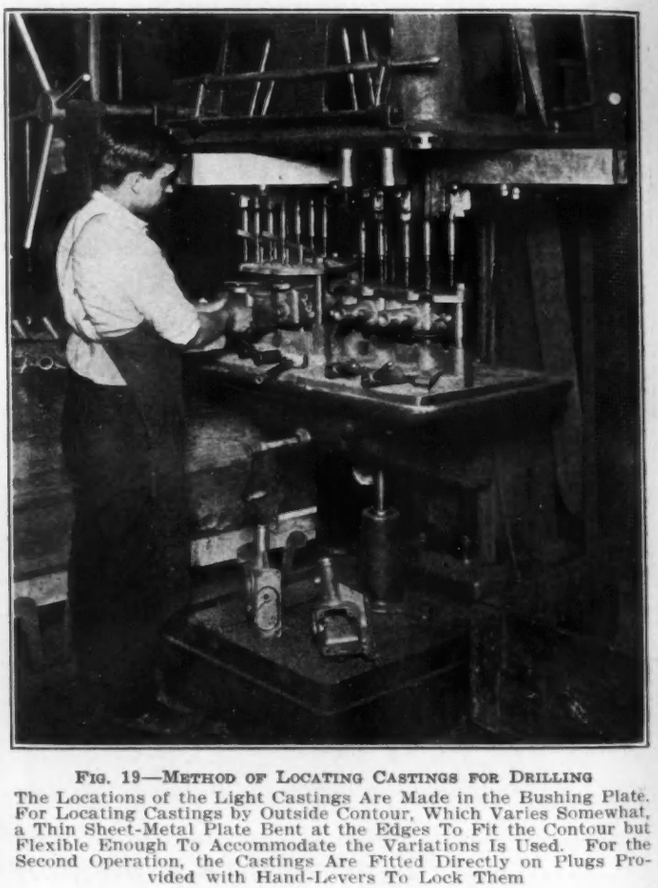


FIG. 19—METHOD OF LOCATING CASTINGS FOR DRILLING

The Locations of the Light Castings Are Made in the Bushing Plate. For Locating Castings by Outside Contour, Which Varies Somewhat, a Thin Sheet-Metal Plate Bent at the Edges To Fit the Contour but Flexible Enough To Accommodate the Variations Is Used. For the Second Operation, the Castings Are Fitted Directly on Plugs Provided with Hand-Levers To Lock Them

the cutting-tools. In this way a simple driving-head can be produced that can be attached to any simple base upon which any fixture can be mounted, such as a heavy line reaming fixture. This tool has given very satisfactory results during constant use for a number of years. In Fig. 14 the work is shown on the fixture ready to be rotated in line with the driving unit. The fixture has been made to rotate to facilitate the taking out and replacing of the bars in the work.

OIL-HOLE DRILLING IN CRANKSHAFTS

The solution of a problem in oil-hole drilling on crankshafts will doubtless be of interest. The holes are drilled diagonally from the crankpins through the cheeks and main-line bearing, and two pairs of holes are drilled in three different directions. Three drilling-machines are

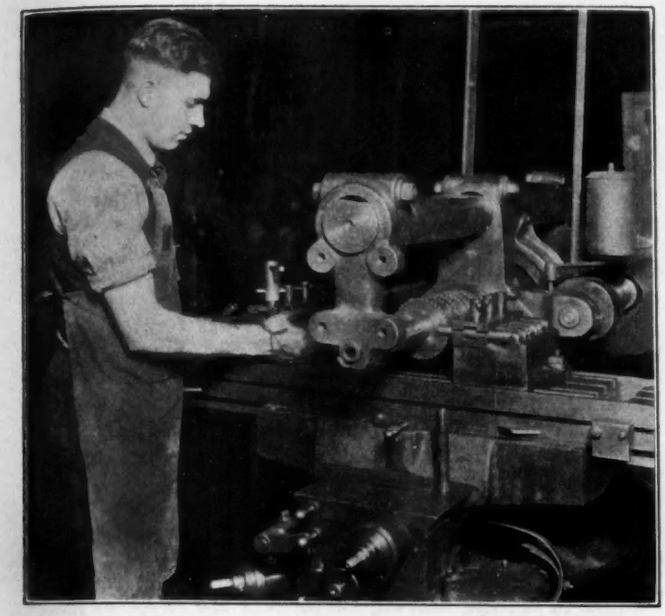


FIG. 20—TIME-SAVING MILLING OPERATION

While the Machine Is Milling Cuts in the Ends of Six Light Shafts in the Fixture at the Right, the Operator Is Loading the Fixture on the Left. The Feed of the Table Is Then Reversed To Bring the Ends of the Uncut Shafts Up to the Cutters on the Left Side. This Method Works Out as Well as Any Indexing Means and Is Much Simpler

used for these operations, each machine carrying two drills that drill two holes in the same direction, as shown in Fig. 15. Each machine drills in a different direction from the others. These machines also have been running very successfully for a number of years, and one operator on the three machines does the work on as many as 50 crankshafts per day.

A phase of the work that had given much trouble in the former hand-operation was the unusual amount of breakage of drills in the work. This was overcome by the use of a special cam which reproduces the hand operation that was necessary when drilling the oil-holes. The holes are of such small diameter that it was thought inadvisable to use oil-drills, that is, drills with small holes through which oil could be forced to assure the drills clearing themselves of the chips. Therefore it was necessary to withdraw the drills after drilling a certain depth and free them of the chips, then return them into the work. The cam for this purpose is of such design that the drills enter the work for a predetermined distance, then are automatically backed out and the drills cleared of the chips by a stream of oil that is constantly forced against the drills at the entrance of the work. The drills then reenter their holes and continue the drilling to a somewhat less depth than the first time, after which the backing out and clearing is repeated. This operation is repeated a number of times, with less drilling each time, until the holes are drilled to the full depth. By this method very little drill breakage occurred after we determined that it was necessary to keep the drills sharp and insisted upon their being sharpened at frequent predetermined periods.

FOUR-DIRECTION DRILLING OPERATION

Although most of the remaining examples do not pertain to operations in the automotive industry, they may be of interest and the methods are all applicable to the industry.

Fig. 16 shows a drill-jig arranged on a standard multiple-drill machine to adapt it for drilling a piece of work in four directions simultaneously. Three horizontal spindles were built directly into the drill-jig and each is driven by a set of bevel-gears from one of the vertical spindles. The feed of the spindles is accomplished by bell-cranks which drive the horizontal drills inward toward the center of the drill-jig, thus drilling three holes in the casting at 120 deg. apart. The casting weighs 36 lb. and can be handled, jigged and completely drilled four ways in 45 sec., that is, 15 or 20 vertical holes and three diagonal holes.

A very simple and effective design of rotating fixture for loading while drilling, thereby saving handling time, is shown in Fig. 17. The same jig is seen in operation in Fig. 18, in which the operator is loading one end of the jig while the holes are being drilled by the machine in the work in the other end. In the castings shown, the holes are ½ in. in diameter by 1½ in. deep, and it is possible to drill about 20 pieces per min.

A quick and effective method of locating light castings for drilling operations is shown in Fig. 19. The locations of the castings are made in the bushing plate, which assures that the location is always correct to the holes that are drilled. The locating of one of these particular pieces was by outside contour, and as the castings were certain to have some variations, considerable experimenting was done to find the best method of locating them. A very satisfactory method was finally devised by using a thin flexible sheet-metal plate bent at the edges to fit the contour of the casting but having flexion enough to take up the variations of the castings. The holes were drilled to take a cover-plate and it was necessary to be very particular about the contour location to be sure that all the covers would fit nicely. For the second operation, this case was fitted directly on plugs

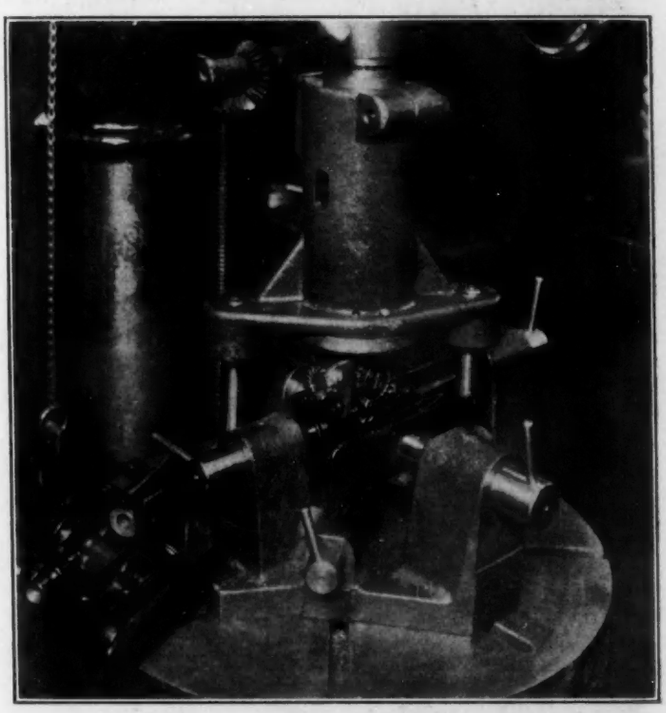


FIG. 21—DRILL-PRESS MADE INTO A MILLING-MACHINE

Four Milling-Cutters Machine Four Bosses on the Four Inner Sides of the Small Cases Shown in and at the Left of the Fixture. This Milling Process Was Devised as a Substitute for Back-Counterboring. Owing to the Small Size of the Work Pieces, the Problem Was To Design Internal Mechanism in the Tool That Would Be Strong Enough To Carry Cutters of Sufficient Size, But the First Effort Was So Successful That the Device Has Been in Operation for Several Years and Is Paying Handsome Dividends

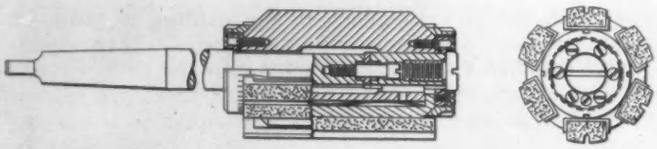


FIG. 22—CYLINDER HONE WITH SPRING-BACKED ABRASIVE MEMBERS
The Flat Spring Shown in the Longitudinal Section Is Stiff Enough To Hold the Stone-Holder against the Beveled Adjusting-Collars at the Ends of the Tool as Firmly when Giving the Final Finish as If the Hone Were a Solid Member. The Only Function of the Springs Is To Flex Enough To Allow the Tool To Enter the Cylinder and the Stones To Remove the Necessary Amount of Excess Metal To Bring the Bore to the Correct Size. The Adjusting Collars Can Be Backed Away from the Beveled Ends of the Stones and Allow the Springs To Force the Stones Outward To Compensate for Wear of Their Faces

provided with hand levers, which are visible in the fixture. This method was also very satisfactory and it rendered possible the turning out of more than two completely drilled cases per minute in the two operations.

A milling operation to produce a cut in the end of shafts is shown in Fig. 20, which is presented as another example of gaining the benefit of loading one fixture while milling work is being done on the pieces in another fixture. This method works out fully as well, and I think is much simpler, than any indexing means.

DRILL-PRESS CONVERTED INTO MILLING-MACHINE

An effective way of making a milling-machine of an ordinary drill-press is shown in Fig. 21. The milling process was devised as an improved substitute for back-counterboring, which had been used previously. Because of the small size of the work piece, the problem was to design internal mechanism strong enough to carry cutters of sufficient diameter to do the work satisfactorily and have long life. This was one of those jobs on which a guarantee could not be given, when the design was started, that it could be built satisfactorily, and a stipulation was made that we would try to reduce the time of the operation provided we would not be criticized too severely if the device failed. The first effort proved successful, however, and the machine was entirely satisfactory. The customer then thought it advisable to make a second unit to have on hand when anything went wrong with the one in operation. A strange fact was that the duplicate unit failed the first time it was put in operation, due, no doubt, to the fact that the heat-treating of the working part was not what it should have been. This instance is cited only to show what a slight margin there may be at times between a brilliant success and a dismal failure. It was fortunate, in this case, that the second unit was not built first, as otherwise the design might have been regarded as a flat failure.

The little unit on which the work is done has four bosses, of which two can be seen in the piece of work lying near the fixture. This piece of equipment has been in successful operation for 2 or 3 years and, so far as I know, the failure of that second unit was the only severe failure. These units wear out rather frequently, because they are in constant use and it is difficult to prevent cast-iron chips from working in and loosening the bearings; however, the machine is paying the company handsome dividends every year.

HONE FOR LAPPING ENGINE-CYLINDERS

The basic principle of all good hones is the same; that is, the finished surface produced should be practically the same as if the hone were a solid member. In the hone shown in Fig. 22 an attempt has been made to accomplish this by inserting behind each abrasive member a spring that is so strong that it will hold the stone-holder against the beveled edges of the adjusting collars at the ends of the tool when it is giving the final finish precisely as if there were no spring. The only duty imposed upon the springs is to flex enough to allow the tool to enter the work and perform its function of removing the necessary stock to come to size automatically. By this method we have been able to keep the cylinder to size merely by adjusting the collars at intervals as the stones wear down.

We have been lapping engine cylinders for the last 12 or 14 years and never have considered it advisable to use any cylinder bearing-surface or any crankshaft or plain bearing that rotated or that received anything like the severe service in a gas engine, without lapping the bearing surface to assure the bearings being round and of proper finish. We have proved to our own satisfaction that lapping more than repays for the time spent in the operation. I do not know of any finishing operation that could be done on an internal-combustion engine that would give an equal amount of satisfaction to the user. Failure to lap the bearing surfaces is the cause of many shortcomings that are now common in many engines. It is a mistake, however, to think that errors in any machining process can be corrected by lapping.

When one becomes familiar with the lapping process, all machined surfaces are poor when checked with a lap; even the finest finish that the grinder can impart is a very poor surface from the lapping point of view. If we thought that a ground surface was good enough for a bearing, we would not hesitate to try it with a lap, because no considerable time would be required to lap the surface; but as all grinding of any kind and all machine work is so rough when checked with a lap, it is realized that the producing of a lapped surface does take some time, and this fact is a true indication that the surface needs this extra lapping work to give it the refinement required if the bearings are to run quietly and have a satisfactory life.

If any doubt exists in the mind of anyone who is not familiar with the lap finish that there is danger of charging the bearings with particles of emery, he can easily convince himself whether this occurs or not by watching the finish that is being produced. A surface that has a tendency to charge always has the appearance of frosted or ground glass, while the high-quality finish that is free from any charging or embedding of abrasive in the bearing has the clear bright appearance of the looking-glass surface. The avoidance of charging is merely a question of using the proper lap-material for the particular material of the bearing to be lapped. One should never use a material in the lap that has anywhere near the hardness of the bearing surface. It must be of soft enough substance to take the abrasive into itself and have no tendency to force this into the work that one is trying to lap, which is indicated by charging the bearing surface. One can always be sure of a correct finish if he will use some hardwood for the final finish. Wooden laps ensure a beautiful finish for the highest type of cylinder practice. This practice is highly desirable in high-class cars, racing engines and, more particularly, in the airplane engine, in which a failure may be disastrous and a success means so much longer life of the engine.

Methods and Means Used for Small-Gear Inspection

By P. W. Rhame[1]

Production Meeting Paper *Illustrated with* Photographs and Charts

ABSTRACT

GREAT attention is necessarily paid to the quality of speedometer gears as regards quietness of operation, free action and long life. From an inspection viewpoint, this control of quality resolves itself into a problem of methods and means. Attention is focused on preventive measures, such as thorough inspection of the cutters and concentrated supervision of the work in progress on the machines. This inspection on the floor of the shop separates questionable work from that which is known to be satisfactory, and the inspector reports all stoppages and trouble on a form that is retyped, multigraphed and distributed to the managing executives, the supervisors and the foremen.

Each inspector is provided with definite written instructions, and each man is required to know these instructions thoroughly and to reread them every two weeks. The instructions are kept uptodate and are enforced by the foreman, and they are checked-up by the head of the division and by the superintendent of inspection. The aim is to confine the supervisory inspection to the effective minimum.

ACCURACY and quietness of operation are the primary objectives sought in the making of our speedometers, and constant attention is focused on these factors throughout the process of manufacture. For testing the final speedometer assembly for quietness of operation, a special silent drive is installed in a quiet room such as that shown in Fig. 1, and the units are held inside a case during the test to determine what the added noise-effects due to resonance are. From an inspection viewpoint, the solution of the problem lies in the proper selection of methods and means of controlling the quality of the parts which are most prominent as the cause of noise, the worms and the gears.

[1] A.S.A.E.—Superintendent of inspection, A. C. Spark Plug Co., Flint, Mich

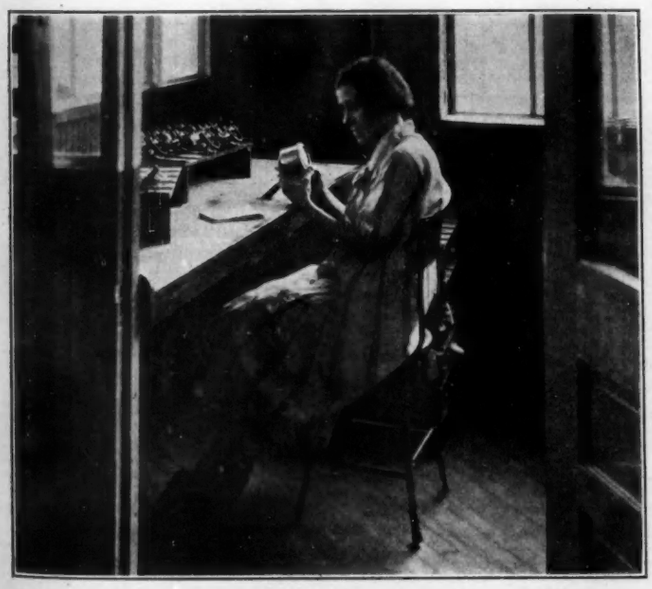


Fig. 1—Testing for Noiselessness of Speedometer Operation
For Testing the Final Speedometer Assembly for Quietness of Operation, a Special Silent Drive Is Installed in a Room Such as That Shown. The Units Are Held Inside a Case during the Test To Determine What the Added Noise-Effects Due To Resonance Are

Methods Used

The inspection system we use on the floor of the shop during the making of the speedometer gears is not radically different from that used by other manufacturers, but some of its details are of interest and are therefore stated.

First, the inspector makes the rounds of all machines every 30 min. or oftener and puts two or three of the last pieces made by each machine into the proper compartment in his tray. The remainder of the finished work at the machine is then set to one side.

Second, the inspector carries the samples to his cen-

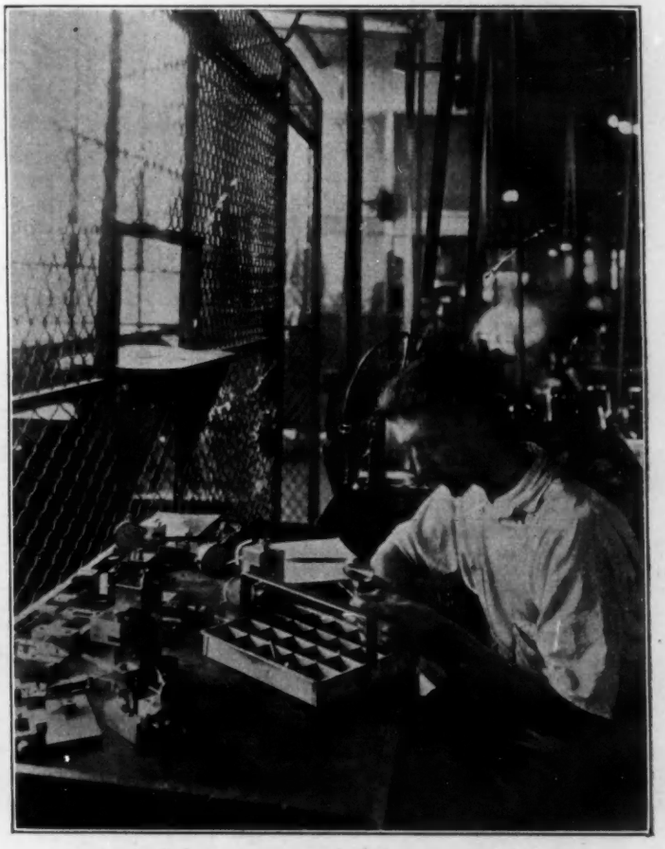


Fig. 2—Centrally Located Gaging Bench and Methods
Here, the Inspector Checks Samples of the Work Being Produced. Gages Are Used for Checking Proper Meshing and Size. A Visual Inspection for Proper Finish Is Made Also

trally located gaging bench and there checks the work with gages for proper meshing and size, as indicated in Fig. 2, and inspects it visually for proper finish. He then returns to the machines and, if the sample parts passed his inspection, the completed pieces previously set aside at each machine are dumped into a so-called "O. K. pan,"

FIG. 3—SEGREGATION OF PERFECT FROM IMPERFECT WORK
If Sample Parts Pass Inspection, the Completed Work Previously Set Aside at Each Machine Is Emptied into a So-Called "O. K. Pan." If Sample Parts Are Rejected by the Inspector, Completed Work Set Aside at Each Machine Goes into a So-Called "N. G. Pan" and, Later, Each of These Units Is Inspected Completely

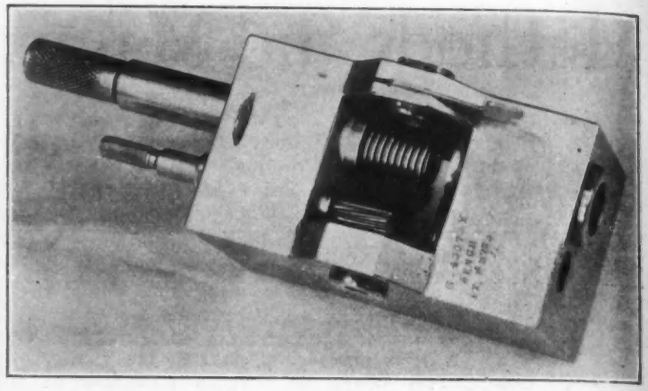


FIG. 5—OLD STYLE GEAR-AND-WORM GAGE
Originally, Gears and Worms Were Checked When Supported by Full Bearings. Later, an Improved Type of Gage Was Developed

as shown in Fig. 3. If the inspector rejected the sample parts, those set aside at each machine go into a so-called "N. G. pan" and, later, each of these units is inspected completely.

Third, the results of his tour of inspection are entered on a special form, reproduced in Fig. 4, by the inspector, so that there is a complete record of the results obtained on all the machines in the department. The substance of this report is typed, multigraphed and distributed daily to the managing executives, the supervisors, the foremen, and others. This reporting feature serves as a check on the work and stimulates interest in it.

The foregoing procedure has proved itself to be an ex-

AC 465 10M-6-26-2763-BMF
Printed in U. S. A.

DEPARTMENT INSPECTOR'S DAILY REPORT

CODE: Symbol √ O. K. | Symbol X Stopped by Inspector | Symbol — Job Completed or Out of Stock | Symbol O Stopped by Production | Symbol | Ditto

Date 8-2-26 Dept. No. 107 Division Speedometer Gears

CLOCK NO.	16		09		13		87		59		02		58		55	67	47	44	
Part No. and Operation	5170 Mill	5022 Hdt	5170 Mill	5022 Hdt	7010 Mill	5725 Mill	5170 Mill		5170 Mill	7010 Hdt	7008 Mill	5022 Hdt	5627 Hdt	"	5725 Hdt	7009 Hdt	5695 Hdt	5615 Hdt	"
Mach. No.	2961	2916	2962	2654	3419	1959	5511		2664	2480	2963	2764	2664	2480	3281	3304	3564	2764	2749
7:30 A. M. to 1:30 P. M.							X A												
8:00 A. M. to 2:00 P. M.																			
8:30 A. M. to 2:30 P. M.					X D														
9:00 A. M. to 3:00 P. M.											X C								
9:30 A. M. to 3:30 P. M.																			
10:00 A. M. to 4:00 P. M.																			
10:30 A. M. to 4:30 P. M.					X B														
11:00 A. M. to 5:00 P. M.																			
11:30 A. M. to 5:30 P. M.																			
12:00 A. M. to 6:00 P. M.																			

List Letters Opposite X and Explain Reasons for Stopped Jobs

A Milling undersize and eccentric; mach. needed adj.
B " " ; mach. needed adj.
C " thrust too close to edge of stock; mach. needed adj.
D " catchy worms due to mislocation.
E
F
G
H
I

B Bailey
112501

FIG. 4—DEPARTMENT INSPECTOR'S DAILY REPORT
The Results of the Tour of Inspection Made by the Inspector in the Shop Are Entered on a Form Such as That Shown. This Furnishes a Complete Record of the Results Obtained on All the Machines in the Department

cellent *preventive* method of inspection which allows the correction of defects to be made before many defective parts are produced.

Equipment for Inspection

Gears and worms can be no more accurate than the hobs, the cutters, the machines, and the gages used during the process of their manufacture. Realizing this fact, we have found it necessary to resort to ground cutters

Fig. 6—New Styles of Gages
These Gages Are Designed To Have Long Large Replaceable Bushings So That Wear Can Be Compensated. The Gage at the Left Is Used for Set-Up and for Inspection Purposes in the Shop. The Indicators Check the Backlash on Both the Worm and the Gear. The Gage at the Right Is Used for 100-Per Cent Checking Work

and to the use of an enlarged stereopticon projection to aid in checking them. Special machines have been designed but, even on these, we have had to resort to the refinement of keeping small chips away from the cutting compound and the collets so as to maintain accurate concentricity of the parts. This is done by flowing the cutting compound through a standard A C oil-filter, visible in Fig. 3. Incidentally, this practice has reduced machine wear materially.

The gages used in this work have undergone a rapid process of evolution that finally has enabled them to meet the demands for accuracy, reliability, speed of checking, and simplicity of maintenance. For example, gears and worms originally were checked when supported by full bearings, as shown in Fig. 5. The one small master-gear had to work freely and backlash was checked by "feel." The maintenance problem was serious; a few tenths of an inch of wear on the bushing altered the results completely. The first master-gears were difficult to make because of warpage, and it was difficult also to check a master-gear. The human element involved in checking by "feel" is never to be relied upon. Confronted by these problems, our gage engineer developed the units illustrated in Fig. 6. They are designed to have long large replaceable bushings, so that wear can be compensated.

Each gage is checked regularly twice a week with hardened master-worms and master-gears. This is done by a man who does nothing else but check and set gages. The gage at the left in Fig. 6 is used for set-up and for inspection purposes in the shop. The indicators check the backlash on both the worm and the gear. The thread of the master-worm for checking the gear is ground to assure accuracy and is supported by double bearings of large size to provide long life. The master-gear is made of a non-warping steel.

The work rests on a U-shaped slot which is adjustable as to height and also for the compensation of wear, thus making possible accurate gaging of center distances within say 0.2 in. The U-shaped-slot feature makes the process convenient and rapid. The gage at the right in Fig. 6 is used for 100-per cent checking work. The length of the master-worm is sufficient to allow more than a complete revolution of the gear, thus automatically checking the worm when the master-gear is cut.

Inspection Forms

In all cases, inspectors are provided with detailed written instructions regarding what to do and how to do it. These are read regularly, kept uptodate and lived up

Subject: STANDARD INSTRUCTIONS FOR FEMALE FLOOR INSPECTOR IN DEPARTMENT #107

Purpose: To have a Record of Responsibilities and Methods,

Equipment: Tools and Supplies.

Bench,
Compartment Carrier,
Forms AC-465,
Gages listed on Operation Sheets for Dept. #107 parts,
Rejection Tag AC-308,
Micrometers.

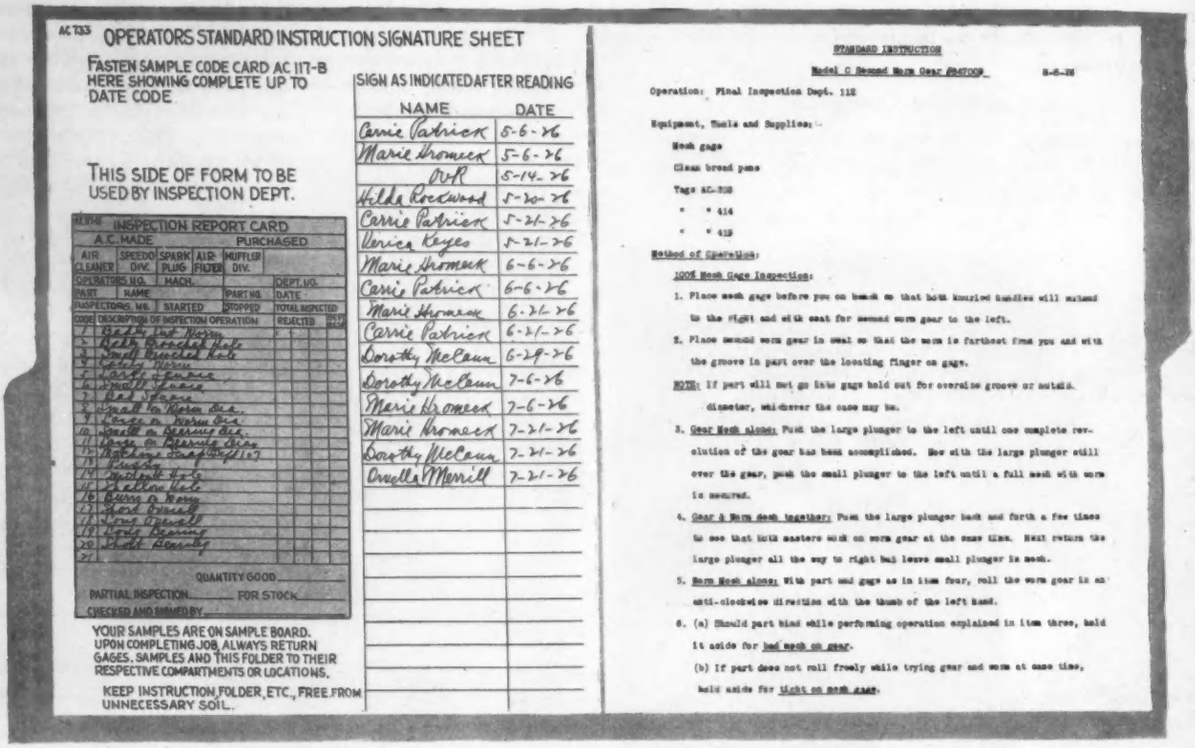
Responsibilities:

1. To see that all operations are being performed according to Standard Instructions and that parts manufactured are within established limits.
2. Make out Report AC-465 daily, reporting any troubles or unusual occurrences with Product, Tools, Fixtures or other equipment.
3. To accept and carry out such special instructions as may be given by Floor Inspector, Foreman or, in his absence, the Chief Speedometer Floor Inspector, and Superintendent of Inspection.

Method of Checking Product:

1. Batch method of inspection is in effect on most parts as follows:
2. The inspector shall make rounds of all machines in operation according to schedule on Form AC-465 (Not Exceeding 30-Minute Intervals). She shall select the last two (2) parts manufactured, and setting aside pan containing parts machined since previous tour, replace pan with an empty one.
3. The parts selected shall be placed in proper part of special carrier (Compartments of which are marked with the machine and operator's number) and taken to a bench where they shall be inspected according to Standard Instructions, using gages listed on Operation Sheets.
4. Result of each tour and check shall be noted on Form AC-465 in duplicate, the original going to the Inspection Office and copy to the Efficiency Department.

Fig. 7—Standard Instruction Sheet for Inspectors
Employes Are Required To Learn These Rules and To Read Them Frequently



AC 733 OPERATORS STANDARD INSTRUCTION SIGNATURE SHEET

FASTEN SAMPLE CODE CARD AC 117-B HERE SHOWING COMPLETE UP TO DATE CODE

THIS SIDE OF FORM TO BE USED BY INSPECTION DEPT.

INSPECTION REPORT CARD

A.C. MADE PURCHASED

AIR CLEANER | SPEEDO DIV. | SPARK PLUG | AIR FILTER | MUFFLER DIV.

OPERATORS NO. | MACH. | DEPT. NO.

PART | NAME | PART NO. | DATE

INSPECTORS NO. | STARTED | STOPPED | TOTAL INSPECTED

CODE	DESCRIPTION OF INSPECTION OPERATION	REJECTED	INIT
1	Axle Int Worm		
2	Axle Bearing Hole		
3	Small Bracket Hole		
4	Carby Worm		
5	Axle Housing		
6	Small Housing		
7	Rod Stops		
8	Shaft to Worm Ass.		
9	Gage a Worm Ass.		
10	Shaft a Bearing Ass.		
11	Gage a Bearing Ass.		
12	Differential Shaft		
13	Pinion		
14	Int Bolt Nut		
15	Shaft Nut		
16	Assy a Worm		
17	Assy Complete		
18	Assy Overall		
19	Test Bearing		
20	Test Assembly		
21			

QUANTITY GOOD

PARTIAL INSPECTION FOR STOCK

CHECKED AND SIGNED BY

YOUR SAMPLES ARE ON SAMPLE BOARD. UPON COMPLETING JOB, ALWAYS RETURN GAGES, SAMPLES AND THIS FOLDER TO THEIR RESPECTIVE COMPARTMENTS OR LOCATIONS.

KEEP INSTRUCTION FOLDER, ETC., FREE FROM UNNECESSARY SOIL.

SIGN AS INDICATED AFTER READING

NAME	DATE
Carrie Patrick	5-6-26
Marie Bromeek	5-6-26
OVR	5-14-26
Hilda Rockwood	5-20-26
Carrie Patrick	5-21-26
Verica Keyes	5-21-26
Marie Bromeek	6-6-26
Carrie Patrick	6-6-26
Marie Bromeek	6-21-26
Carrie Patrick	6-21-26
Dorothy McCann	6-29-26
Dorothy McCann	7-6-26
Marie Bromeek	7-6-26
Marie Bromeek	7-21-26
Dorothy McCann	7-21-26
Orella Merrill	7-21-26

STANDARD INSTRUCTION

Model C Second Worm Gear #84709 8-6-26

Operation: Final Inspection Dept. 112

Equipment, Tools and Supplies:-

Mesh gage

Clean bread pans

Tags AC-733

" " 414

" " 419

Method of Operation:

100% Mesh Gage Inspection:

1. Place mesh gage before you on bench so that both knurled handles will extend to the right and with seat for second worm gear to the left.
2. Place second worm gear in seat so that the worm is farthest from you and with the groove in part over the locating finger on gage.

NOTE: If part will not go into gage hold out for oversize groove or outside diameter, whichever the case may be.

3. Gear Mesh alone: Push the large plunger to the left until one complete revolution of the gear has been accomplished. Now with the large plunger still over the gear, push the small plunger to the left until a full mesh with worm is secured.
4. Gear & Worm mesh together: Push the large plunger back and forth a few times to see that both centers with on worm gear at the same time. Next return the large plunger all the way to right but leave small plunger in mesh.
5. Worm Mesh alone: With part and gage as in item four, roll the worm gear in an anti-clockwise direction with the thumb of the left hand.
6. (a) Should part bind while performing operation explained in item three, hold it aside for bad mesh on gear.

(b) If part does not roll freely while trying gear and worm at same time, hold aside for tight on mesh gear.

FIG. 8—STANDARD INSTRUCTIONS FOR INSPECTORS WHO WORK AT BENCHES
Records of This Sort Are Necessary If Uniform Standards of Rejection Are To Be Maintained

FIG. 9—UNIVERSAL TYPES OF MESH-GAGES
In These Types, Checking Means for Both Center Distance and Diameter Changes Can Be Accommodated in One Gage. The Method of Checking Backlash Is Evident Also

to. Sample forms are shown in Figs. 7 and 8. We feel that these forms are necessary, if uniform standards of rejection are to be maintained.

A somewhat universal type of gage for checking transmission gears is shown in Fig. 9. By the use of different plugs, checking means for both center distance and diameter changes can be accommodated in one gage. Fig. 9 also shows in detail our method of checking backlash. In this instance the gage is slid under the indicator while the pointer rests on a horizontal tooth of the pinion. The master worm is then held and the pinion is moved. As already mentioned, all gages are checked regularly by gage checkers.

Inspection supervision always should aim to be the effective minimum and never should be content to stop the development of systems, methods and equipment which will attain that end.

SWITZERLAND

SWITZERLAND stands supreme in Europe and perhaps in the world in the application of organized intelligence to a severe problem of national economics. Wholly devoid of natural resources, except her soil, an abundance of rock, her modest forest reserves, her water power, and her scenery, she is yet the supreme example of evenly distributed modern comfort in her scale of living. Her industrial system, based on the application of the maximum of highly trained intelligence and skill to the minimum of imported raw materials, is a wholly unique example of deliberate economic selection. That is another way of saying that Switzerland is probably the best engineering country in Europe. The famous Polytechnic Institute at Zurich and the numerous technical middle schools that dot the several cantons have been direct factors in this scheme for technical education of all the countries east of the Rhine and maintain their place among the most noteworthy in Europe today.—W. E. Wickenden in *Technology Review*.

Vol. XIX October, 1926 No. 4

Transportation by Conveyor

By PAUL PHELPS[1] AND N. H. PREBLE[1]

PRODUCTION MEETING PAPER *Illustrated with* PHOTOGRAPHS AND DRAWINGS

ABSTRACT

CITING in outline seven fundamental operations that embody in principle the complex problems of production of the modern automobile, the authors explain how mechanical handling-systems can be utilized for the accomplishment of transportation or of assembly or of both combined in all these specified procedures. Various forms of conveyor are illustrated and their application to obviate handling-difficulties, to increase the speed of transporting parts and to augment the rapidity of assembly is described.

Reductions in cost due to conveyor installations in several types of automobile plant are discussed. In one instance, manual handling was superseded and the saving in labor cost paid for the installation of the equipment within a few months; in another, the avoidance of traffic congestion within the plant was an asset; in a third, a conveyor installation costing more than $80,000 fully paid for itself within 6 months and then saved $800 per day.

Difficulties presented by such problems as returning empty mill-trucks to their proper starting-point, combining transportation with assembly, conserving floor-space, and overcoming awkward conditions are mentioned, and details of how these hindrances were minimized are stated.

THE production of the modern automobile, although presenting many complex problems, can be reduced in principle to a certain few fundamental operations. In all these operations mechanical handling-systems or, more broadly speaking, conveyors, play a major and very important part because transportation, in one form or another, is almost as large a factor as is the actual manufacture. The operations can be outlined approximately and briefly as:

(1) Receiving and storing raw material
(2) Transporting this material to the machine-shop, the forge, the foundry, or other manufacturing department
(3) Machining, forging or otherwise fabricating the individual parts
(4) Transporting these parts to the sub-assembly
(5) Performing the sub-assembly operations, such as on the engine, the axle, the tranmission, the body assembly, and the like
(6) Transporting the various sub-assemblies and finished parts to the final assembly
(7) Making the final assembly, testing and shipping the completed car

As a whole, the automotive industry does not need to be "sold" on the advantages of mechanical handling; it recognizes that properly designed equipment, properly installed, will effect great savings in direct and in indirect labor and decrease in-process inventory, conserve floor-space and serve as a mechanical pace-maker to speed and regulate production and simplify its control. The head of one of the larger automotive companies even goes so far as to say that: mechanical handling with its attendant pace-making is the greatest single factor in making possible a better than pre-war automobile at a less than pre-war price.

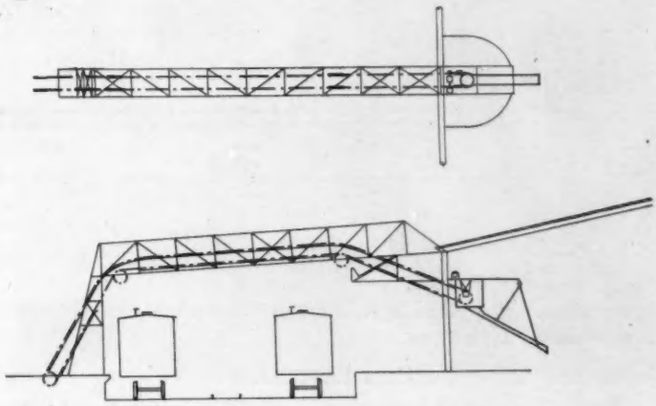


FIG. 1—STOCK CONVEYOR AT AN AXLE PLANT
This Conveyor Equipment Handles Rough Castings from the Receiving Dock to the Machine-Shop. It Is of the Double-Strand Trough-and-Drag Type, with Channel Flights Discharging onto a Swinging Chute Which Feeds into Bins Handled by Lift Trucks to the Various Machine-Tools

In the space at our disposal, it is manifestly impossible to describe fully all the varied applications of mechanical handling-equipment; each application is a problem and a study in itself, requiring careful thought and broad experience for its proper solution. It would be extreme folly to attempt to set down any general rules to be followed blindly. All we can hope to do is to illustrate some particular problems and describe the means taken for their solution.

We are inclined to feel that, in general, the problems of sub-assembly and of final assembly have been solved. Further refinement is undoubtedly possible but, in the main, that type of handling equipment is well understood and is generally employed. With this thought in mind we feel that in presenting this paper the emphasis should be placed more on the conveyor designed purely for transportation or for transportation combined with some more or less minor manufacturing processes such as painting

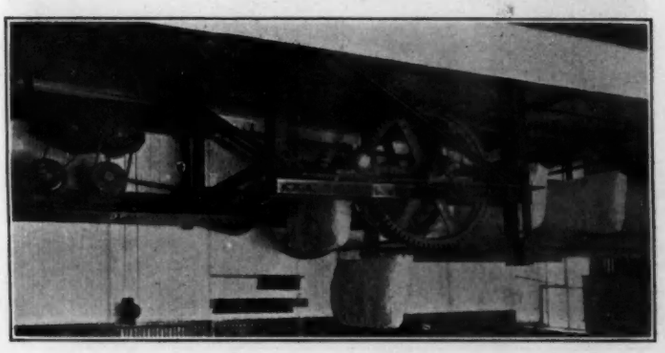


FIG. 2—SEAT-CUSHION CONVEYOR IN A BODY-BUILDING PLANT
The Seat-Cushions Are Received on the Ground Floor and Must Be Carried to the Sixth Floor for Upholstering. The Cushions Are Hung on Hooks and Are Carried outside the Building and across the Roof to the Upholstering Department, Where They Are Unloaded as Shown in Fig. 3

[1] Mechanical Handling Systems, Inc., Detroit.

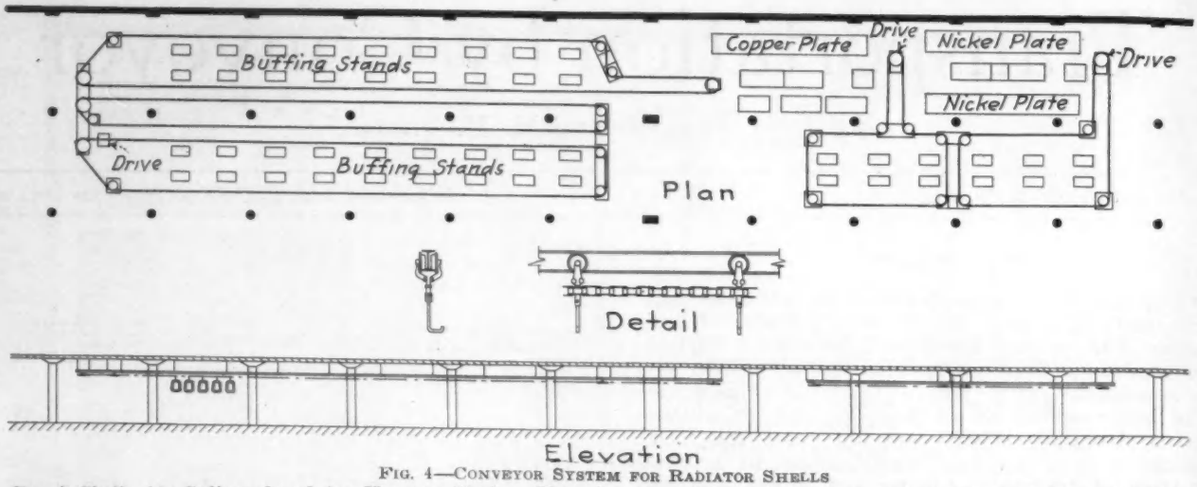


FIG. 4—CONVEYOR SYSTEM FOR RADIATOR SHELLS
Rough Shells Are Delivered and Are Hung on Hooks. They Are Carried by the Conveyor to the Various Buffing and Plating Operations in the Plating Department

and the like. It is here that a large field for further improvement is open.

COST REDUCTION

When we consider that the cost of an electrical horsepower employed in the moving of material is roughly a few cents per hour, while the man horsepower will cost in the neighborhood of 50 cents per hr., we can visualize immediately important possible cost savings. In addition, the indirect savings in improved manufacturing conditions may easily be even more important. An instance of this is shown in an installation of conveyor equipment for handling rough castings from the receiving dock to the machine-shop in an axle plant, the layout of which is shown in Fig. 1. All incoming stock must be received from the outer of three spur-tracks. The center track is largely taken-up by switching, while the inner track must be reserved for outgoing shipments. Formerly, all castings were handled literally from hand to hand, either through or around cars from the receiving dock to the machine-shop. Two conveyors were installed, which have replaced all of this manual handling and resulted in labor savings which paid for the entire installation in a matter of a few months. Further, there is no possibility of delay in the flow of the required parts. The conveyor is of the double-strand, trough-and-drag type, with channel flights discharging onto a swinging chute which feeds into bins handled by lift trucks to the various machine-tools.

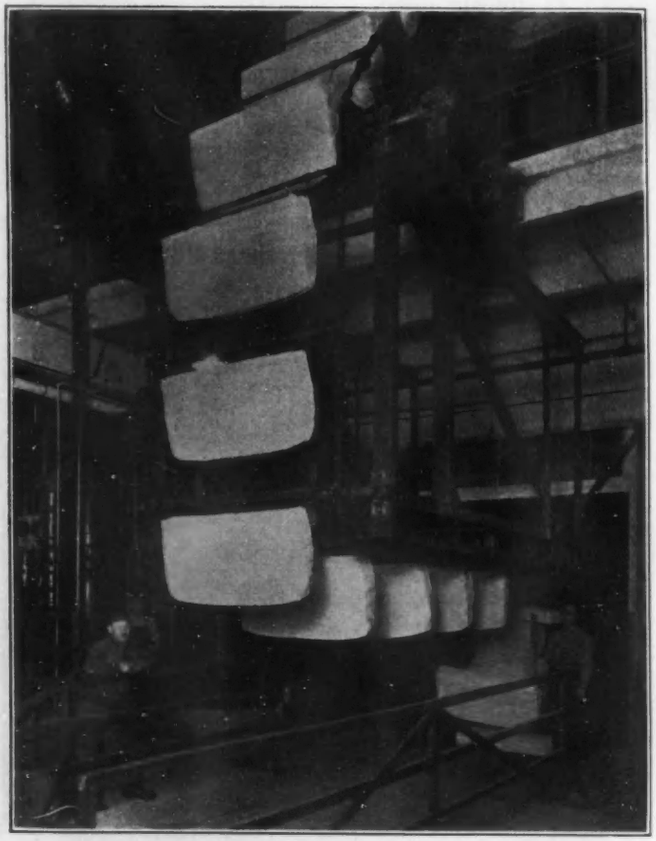


FIG. 3—DELIVERY END OF THE CONVEYOR SHOWN IN FIG. 2
The Seat-Cushions Are Received by Motor-Truck and, Although Light, They Are Bulky. If Handled by Elevator, They Would Interfere Seriously with the Transportation of Other Material through the Plant. Hence, the Conveyor Completely Relieved Serious Traffic-Congestion

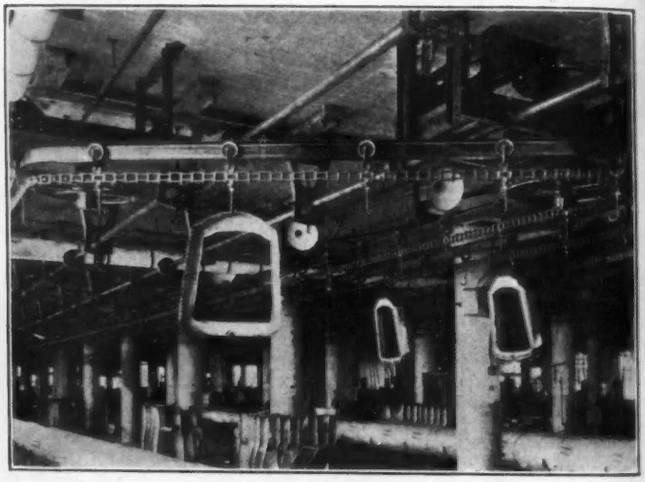


FIG. 5—RADIATOR-SHELL CONVEYOR IN OPERATION
Three Conveyors Are Driven from a Single Power-Unit, Resulting in Absolute Synchronism of Speed and Reducing the Initial Cost of Installation. No Floor-Space Is Occupied by Any of the Conveyor Equipment, Which Does Not Interfere with the Installation of Exhaust Ducts from the Buffing Wheels and the Tanks

Another raw-stock handling-problem is illustrated in a body-building plant. Here, seat-cushions are received on the ground floor and must be carried to the sixth floor for upholstering. The cushions are received by motor-truck and, although light, they are bulky; and if handled

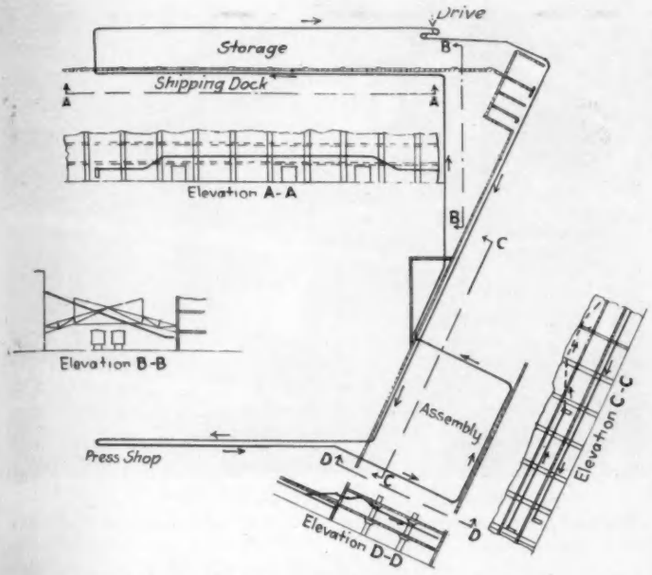


FIG. 6—CONVEYOR FOR TRANSPORTING METAL DOOR-PANELS

The Metal Door-Panels Are Carried from the Press-Shop to the Second Floor for Assembly with the Wood Frames. After Assembly, Some of the Doors Are Removed and Are Distributed by Other Conveyors to the Body Assembly-Lines. The Remaining Doors Pass Out through the Roof, through the Train-Shed Trusses and Then Down along the Shipping Dock for Shipment to Assembly Plants. If Shipments Are Not To Be Made, the Doors Pass On into the Stock-Room for Storage, While the Empty Chain Returns through the Basement to the Starting-Point. The Chain Is Approximately 1600 Ft. Long. The Only Manual Labor Involved Is That Required To Hang Doors on and Take Doors off the Chain

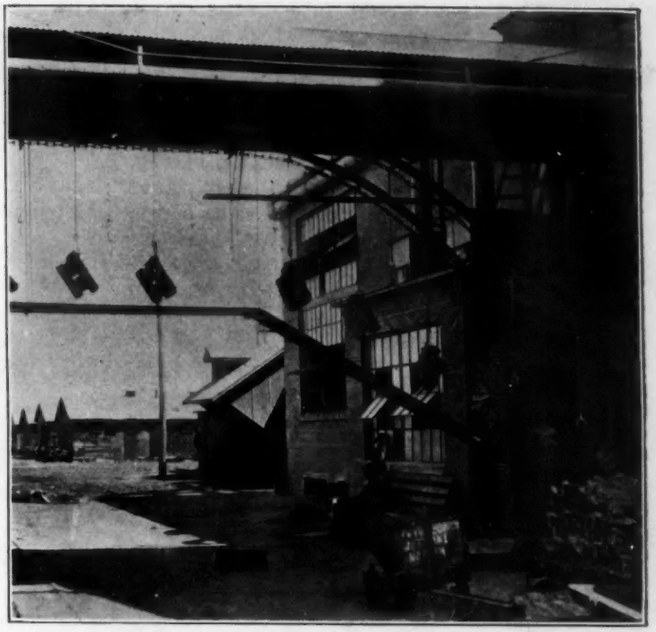


FIG. 8—CONVEYOR INSTALLATION AT A FOUNDRY

Cylinder-Block Castings Are Picked-Up from the Knockout Floor, Suspended from the Conveyor Hooks and Passed through a Sand-Blast Cabinet Where They Are Sand-Blasted while moving. They Then Pass Out of the Foundry Building, Up over the Driveway Shown and into the Machine-Shop, Where They Are Removed from the Conveyor

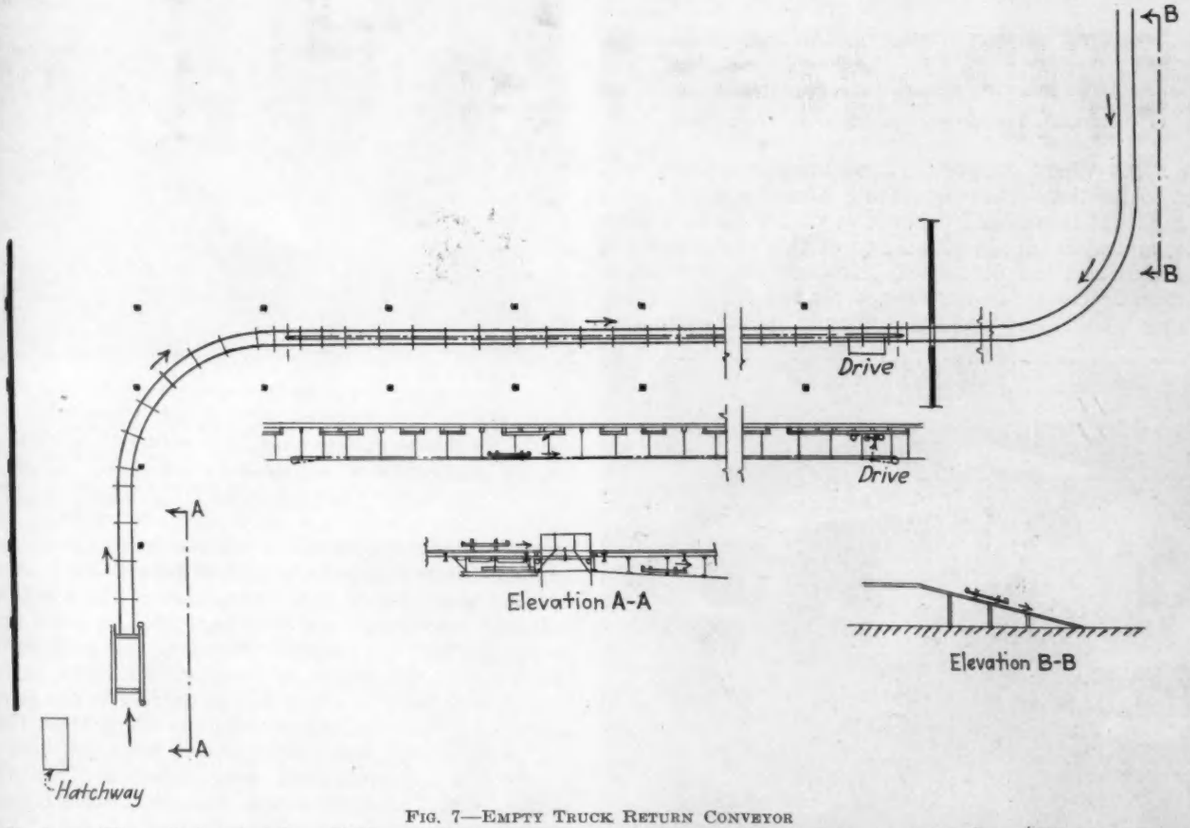


FIG. 7—EMPTY TRUCK RETURN CONVEYOR

In Shops Where Bodies Are Carried through the Paneling, the Painting and the Trimming Operations on Trucks, the Return of the Empty Trucks to the Framing Jigs Presents an Awkward Transportation-Problem. In the Layout Shown, Finished Bodies Are Lowered through a Hatchway to the Truck for Shipment. Immediately Adjacent to This Hatchway Is Another Equipped with a Platform Operated by Air-Pressure onto Which the Empty Truck Is Pushed and by Which It Is Lowered To Line Up with a Track Suspended from the Ceiling Below. When Properly Lowered, a Second Air-Pressure Cylinder Automatically Comes into Operation and Pushes the Truck Forward, Free of the Elevator Platform, at the Same Time Advancing All Trucks Which Are Already on the Line. After Passing Around the Curve, the Trucks Are Picked-Up by a Single-Strand Chain-Conveyor, Are Carried by It across the Building and Are Again Pushed around a Curve to the Gravity Discharge Adjacent to the Framing Jigs

by elevator, they would interfere seriously with the transportation of other material through the plant. The conveyor, the loading end of which is shown in Fig. 2, was installed to meet this situation. The cushions are hung on hooks and are carried outside the building and across the roof to the upholstering department, where they are unloaded at the point shown in Fig. 3. In this instance no very startling saving in labor costs was effected, but a traffic congestion which was extremely serious was completely relieved.

In general, it should be recognized that any system of floor trucking is almost sure to produce one or more

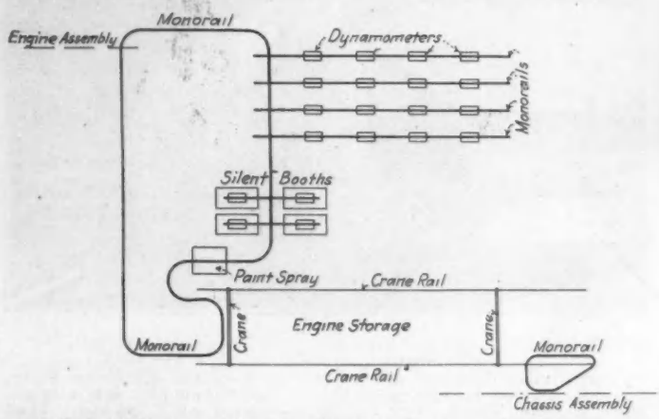


FIG. 9—MONORAIL SYSTEM USED FOR ENGINE BLOCK-TEST
Engines Are Transferred from the Assembly Conveyor by Means of a Hand-Pushed-Trolley System to the Storage Loop in a Dynamometer-Room. They Are Picked-Up as Wanted by Air-Hoists on Trolleys Running Over the Test-Stands and Carried into Position for Testing. After Test, Other Hoists Pick-Up the Engines and Transfer Them to Another Monorail Which Runs Alongside the Silent-Test Booths and Has a Track into Each Booth. After Silent Test, the Engines Come Out on the Same Track, Pass through a Paint-Spray Booth and Then under a Crane over the Storage Racks, Where They Are Stored Until Transferred Again by a Second Crane to Monorails Passing Over the Final Assembly-Lines

tight spots where congestion and attendant delay will occur. Also floor-space represents a capital investment which should be utilized productively. By some system of mechanical handling, congestion of this sort often can be avoided and the floor-space left clear for productive operations. The foregoing are merely two cases of stock handling. Other problems perhaps can be served better

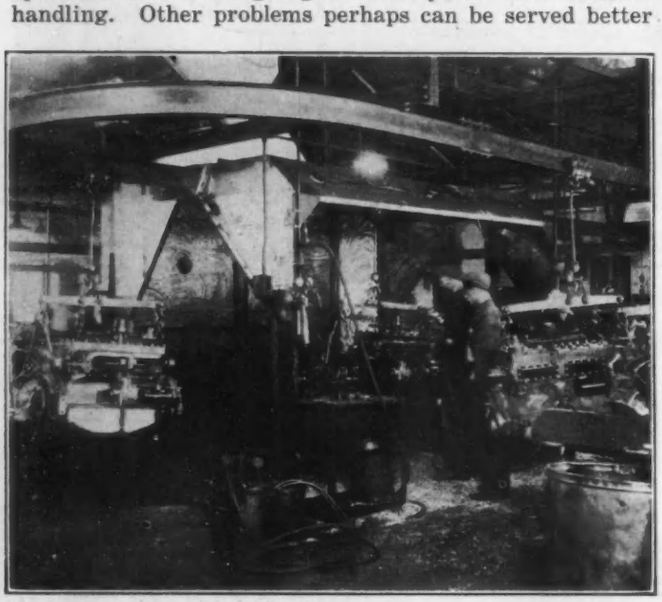


FIG. 10—PAINT-SPRAY BOOTH EQUIPPED WITH MONORAIL CONVEYOR
Part of the System for Conveying Engines That Is Illustrated in Fig. 9

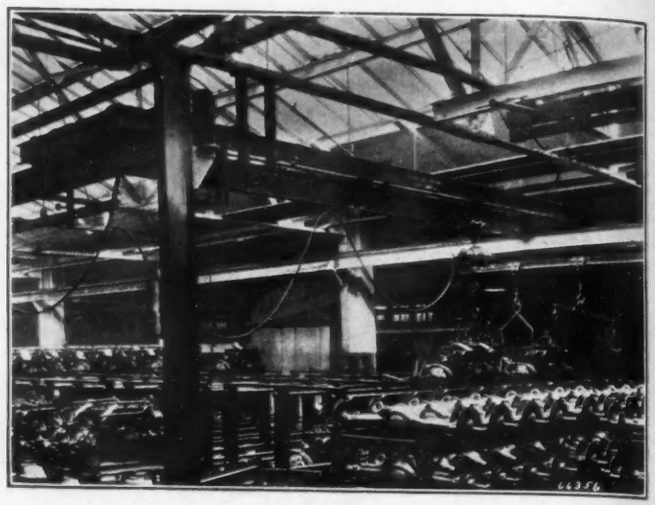


FIG. 11—STORAGE RACKS AND CRANE FOR HANDLING
Engines and Axles Are Handled to and from Storage by the Overhead Crane Shown

by gravity rollers, cranes or hoists or by different adaptations of the conveyor principle.

TRANSPORTATION OF PARTS

In the machine-shop itself, the transportation of individual parts from machine to machine is most frequently left to the tote box or truck, and to hand power, but the

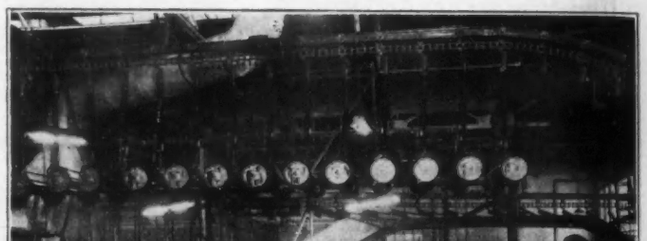


FIG. 12—CONVEYOR HANDLING OF REAR-AXLES
After Coming Off the Assembly Conveyor, Rear-Axles Are Hung on Hooks Suspended from the Conveyor Chain. The End of the Third Member Is Inserted into an Open Tube with a Closed Top That Is Attached to the Suspension-Rod. The Axles First Pass through a Steam-Chamber and Thence, after Forced Drying, to the Paint-Spray Booth, Where They Are Sprayed Automatically. The Conveyor Then Turns Back and into the Drying-Oven

conveyor can be adapted to such a transportation problem as, for example, in a piston department. A monoveyor, a name which is a contraction of the words monorail and conveyor, runs over the machine-tools and the inspection and the assembly benches. As each operation is completed, the piston is hung on the hooks suspended from the monoveyor chain and is carried to the following operation. The entire equipment is hung from the ceiling, leaving the floor clear of all material, and is at a height to give full head-room underneath the pistons.

This same principle could well be adapted to other machining operations. Specially shaped hooks can be designed to carry parts as required, or the hook can be replaced by boxes or trays carrying more than one piece. Where heavy parts are to be handled such as cylinder-blocks and the like, the use of gravity rollers will facilitate the moving of the material and, in many cases, will

decrease considerably the lifting required. This type of conveyor will not, however, effect a full saving in floor-space.

Another installation of a similar type is shown by the layout of monoveyors which is illustrated in Fig. 4. These have been installed in a radiator-shell plating-department. Rough shells are delivered and are hung on hooks and are carried by means of the monoveyor to the various buffing and plating operations. Here we have an example of a multiple drive, as shown in Fig. 5, taken before the buffing-wheels and exhaust system were installed. Three monoveyors are driven from a single power-unit, resulting in absolute synchronization of speed on the three lines and also effecting a reduction in the initial cost of the installation. Here again, floor-space is not occupied in any way by the equipment, and it does not interfere with the installation of the exhaust ducts from the buffing-wheels and the tanks.

Another installation which illustrates clearly the extreme flexibility of the monoveyor is shown by the outline layout-diagram in Fig. 6. Metal door-panels are carried from the press-shop to the second floor for assembly with the wood frames. After assembly, some of the doors are removed and distributed by other monoveyors to the body assembly-lines. The remaining doors pass out through the roof, through the train-shed trusses and then down along the shipping dock for shipment to assembly plants. If shipments are not to be made, the doors are carried into the stock-room for storage, while the empty chain returns through the basement to the starting-point. Here we have a single chain, approximately 1600 ft. long, which turns in the horizontal plane, travels from the basement to the peak of the train-shed trusses and down again. At no place is floor-space occupied, and no labor is involved in the transportation of the doors except hanging them on and taking them off the chain hooks.

Other Transportation Problems

The foregoing are examples of simple transportation between operations in the manufacturing process. In addition, other internal transportation-problems are met, such, for example, as the case of body-building shops where bodies are carried through the paneling, the painting and the trimming operations on trucks. Frequently, the return of the empty trucks to the framing jigs presents an awkward transportation-problem. In one shop this has been solved by the layout shown in Fig. 7. Finished bodies are lowered through a hatchway to the truck for shipment. Immediately adjacent to this hatchway is another equipped with a platform operated by air-pressure onto which the empty truck is pushed and by which it is lowered to line-up with a track suspended

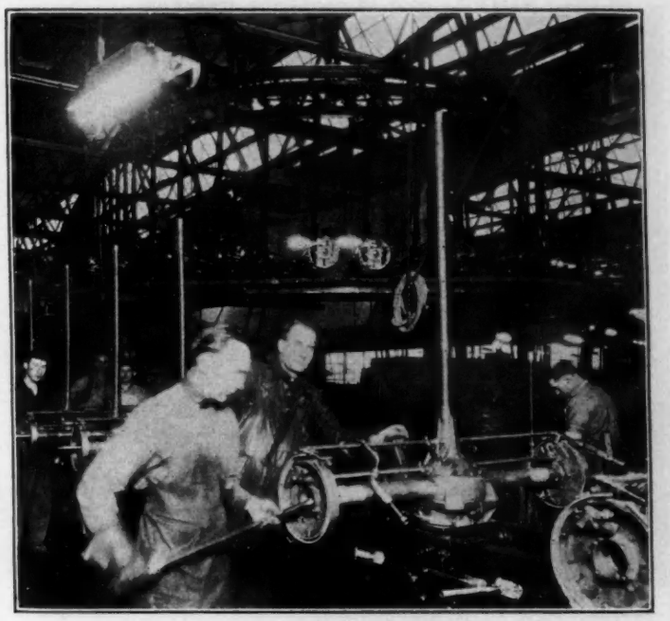


Fig. 13—Turn of the Conveyor Shown in Fig. 12
The Elevation of the Conveyor as It Turns To Enter the Drying-Oven Is Such as To Allow Full Head-Room Underneath

Fig. 14—Conveyor System in a Recent Body-Building Plant
Stamping and Press Work Are Done on the Ground Floor and All Transportation of Parts Is by Conveyors. After Certain Operations, All Parts Are Hung on Four Conveyors That Run to the Fourth Floor Where the Continuous Enameling Ovens Are Located. At the Loading End of the Conveyors That Enter the Ovens, Shown in the Illustration, the Parts Are Transferred from the Transportation Conveyors and Are Hung on Hooks from the Oven-Conveyor Rods

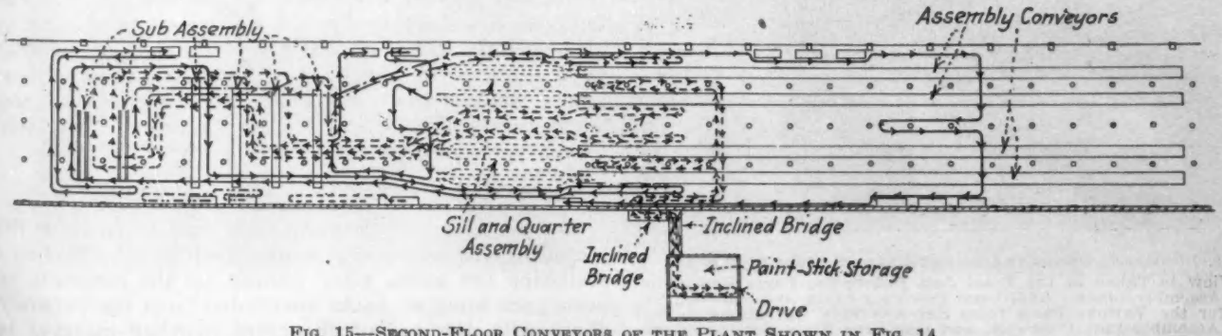


Fig. 15—Second-Floor Conveyors of the Plant Shown in Fig. 14
After Enameling, the Parts Mentioned for Fig. 14 Are Again Hung on a Second Series of Five Conveyors Which Carry Them Down to the Second Floor Where the Bodies Are Assembled for Shipment

TABLE 1—COST OF CONVEYOR OPERATION

Depreciation, $9,000 Over a Period of 10 Years	$900.00
Average Interest, Allowing for Interest Earned by the Depreciation Reserve (11 ÷ 10) × ½ ($9,000 × $0.06)	297.00
Repairs and Maintenance Allowance, Including Oiling	950.00
Total Annual Fixed Expense	$2,147.00
Daily Fixed Expense, $2,147 ÷ 276	$7.78
Expense for Power, 25 Kw-Hr. at $0.025	.63
Total Daily Cost	$8.41
Total Cost per Cylinder-Block Handled, $8.41 ÷ 1800	$0.0047
Savings Effected	
Cost of Two Electric Trucks with Four Trailers, at $0.019 per Casting × 1800 per Day	$34.20
Cost of Operating the Conveyor Per Day	8.41
Net Daily Saving	$25.79
Annual Saving, $25.79 × 276	$7,118.04
Annual Return on the Investment, per cent	79
Former Handling Cost Expressed as a Percentage of the Payroll for That Section	91
Present Handling Cost Expressed as a Percentage of the Payroll for That Section	22½

from the ceiling below. When properly lowered, a second air-pressure cylinder automatically comes into operation and pushes the truck forward, free of the elevator platform, at the same time advancing all trucks which are already on the line. After passing around the curve, the trucks are picked-up by a single-strand chain-conveyor, are carried by it across the building and are again pushed around a curve to the gravity discharge adjacent to the framing jigs. Here again no floor-space is occupied by the equipment except that at the discharge point.

FIG. 16—OTHER CONVEYORS IN THE PLANT SHOWN IN FIG. 14

The View Is Taken at the Point Just Before the Parts Reach the Body Assembly-Lines. Additional Conveyor-Lines Are Provided To Transfer the Various Parts from Sub-Assembly Operations to the Final Assembly-Line Conveyor, and One Line Runs Outside of the Building To Bring in to the Proper Point the Paint-Stick Returned from the Trim Department Located in Another Building

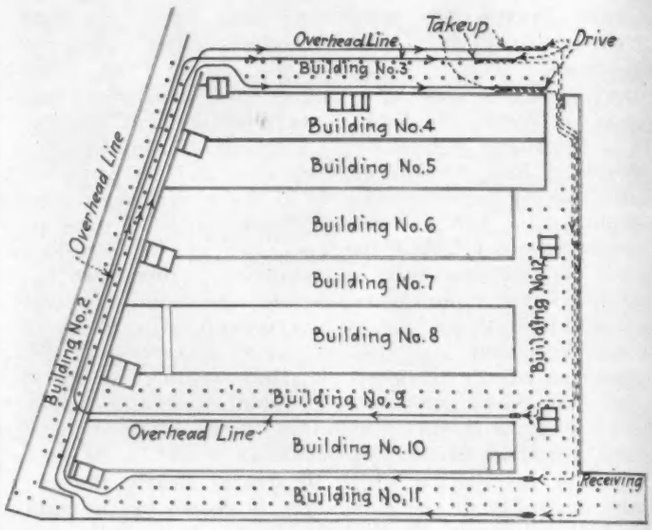


FIG. 17—CONVEYORS PROVIDING BOTH TRANSPORTATION AND FINAL ASSEMBLY

They Illustrate the Possibilities of Construction in Which a Chain Runs on Edge. There Are Three Separate Conveyors; Two Are Located on the Floor and Carry Bodies Received from the Body-Making Plant. Trim and Assembly Operations Are Performed As Bodies Pass along the Line. The Third Conveyor-Line Runs Overhead; It Serves Mainly for Storage But Is Also for the Transportation of Bodies Received Complete from Outside Sources

In the foundry installation shown in Fig. 8, we have an instance of transportation combined with an operation; that is, sand-blasting. Here cylinder-block castings are picked-up from the knockout floor, suspended from the monoveyor hooks and passed through a sand-blast cabinet where they are sand-blasted while moving. They then pass out of the foundry building, up over the driveway as shown in Fig. 8 and into the machine-shop, where they are removed from the conveyor. A Neilsen's survey of this installation shows the results given in Table 1.

The concentration of sub-assemblies and parts at the final assembly-line, frequently presents a difficult problem. One method of handling engines has been worked out as shown in Fig. 9. Engines are transferred from the assembly conveyor by means of a hand-pushed-trolley system to the storage loop in a dynamometer-room. They are picked-up as wanted by air-hoists on trolleys running over the test-stands and carried into position for testing. After test, other hoists pick-up the engines and transfer them to another monorail which runs alongside the silent-test booths and has a track into each booth. After silent test, the engines come out on the same track, pass through a paint-spray booth and then under a crane over the storage racks, where they are stored as required until transferred again by a second crane to monorails passing over the final assembly-lines. Front and rear-axles are brought in by truck and also are carried over the assembly conveyor by means of monorails. In the test-room, the lines of track equipped with air-hoists run over the test-stands. Fig. 10 shows the paint-spray booth. The storage racks and crane, for handling to and from storage, are shown in Fig. 11.

REAR-AXLE AND BODY HANDLING

The handling of rear axles after final assembly is illustrated by the monoveyor shown in Fig. 12. In this installation the axles, after coming off the assembly conveyor, are hung on hooks suspended from the monoveyor chain with the end of the third member inserted into an open tube with a closed top that is attached to the

suspension-rod. The axles first pass through a steam-chamber and thence, after forced drying, to the paint-spray booth where they are sprayed automatically. The conveyor then turns back and into the drying-oven, the elevation of the conveyor being such as to provide full head-room underneath. The turn before entering the drying-oven is shown in Fig. 13. After drying, the axles are in this case carried direct to the shipping dock for shipment to the assembly plants, but the same type of equipment could be used to transport direct to the final assembly-line. The length of the line, together with close spacing of carrying hooks, results in considerable storage acting as a cushion in case of shutdown of the final assembly-line.

In one of the new body-building plants put into operation in the spring of 1926, which produces an all-steel body having an enamel finish baked at a high temperature and which is enameled before assembly, all transportation of parts is by means of monoveyors. The general layout of the plant provides for the stamping and press work on the first floor. After certain operations have been performed, all parts are hung on four monoveyors running up to the fourth floor, where the continuous enamel-ovens are located. Fig. 14 shows these monoveyors at the loading end of the conveyors that enter the ovens, at which point they are transferred from the transportation monoveyors and hung on hooks from the oven-conveyor rods. After enameling, the parts are again hung on a second series of five monoveyors which carry them down to the second floor where the bodies are assembled ready for shipment. Fig. 15 shows the layout of the monoveyors on this floor, and Fig. 16 is a view taken on this floor at the point just before the parts reach the body assembly-lines. Additional conveyor-lines are provided to transfer the various parts from sub-assembly operations to the final assembly-line conveyor, and one line runs outside of the building to bring in to the proper point the paint-stick returned from the trim department located in another building.

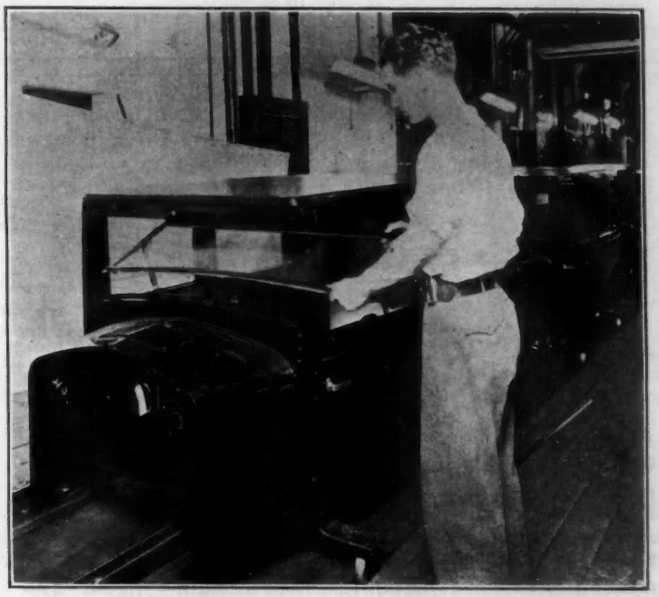


FIG. 18—PERFORMANCE OF A BODY ASSEMBLY-OPERATION
One of the Operations of Assembling a Body as It Passes along the Conveyor Assembly-Line of the System Illustrated in Fig. 17 Is Shown

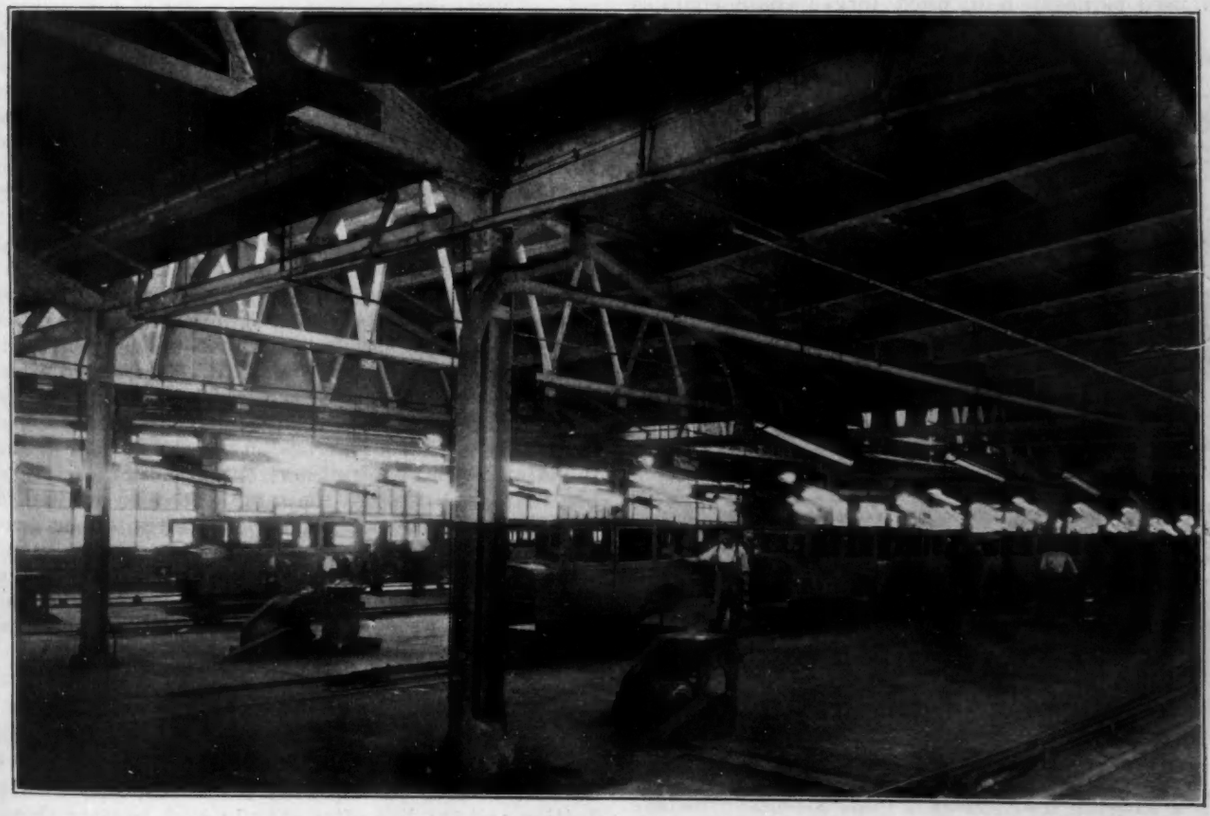


FIG. 19—EXAMPLE OF OFFSETTING A CHAIN CONVEYOR
A Chain That Runs Flat Can Be Offset without Difficulty If the Radius of Curvature Is Great Enough. In the View Shown, the Body Assembly-Line Starts in an Old Building and Ends in a Later Addition, the Columns of the Two Buildings Being Out of Line. No Difficulty Was Experienced in Offsetting the Chain about 8 Ft., and No Special Hold-Down Device Was Required; the Chain Simply Runs Free in a Channel Section

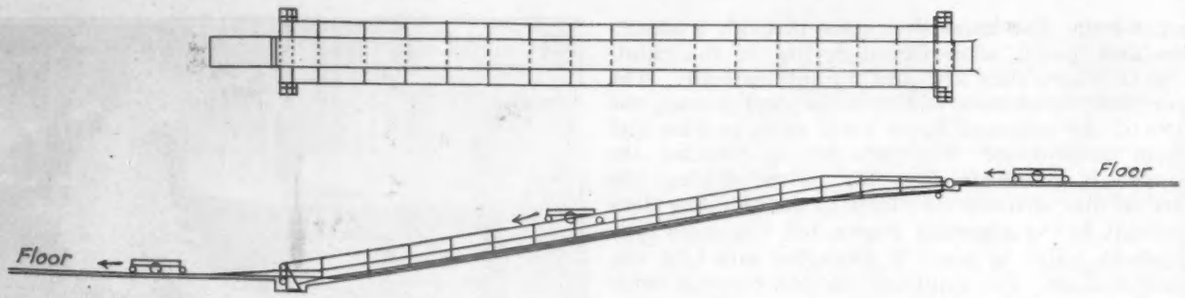


FIG. 20—RETARDING CONVEYOR FROM A FIRST FLOOR TO A BASEMENT
In This Instance, All Pieces Such as Panels and Other Stampings Were Loaded on Mill Trucks in the Press-Room and Had To Be Conveyed Down a Rather Steep Ramp to the Shipping Platform Where They Were Pushed with Their Load onto Trucks for Shipment. The Height of the Loads Made It Necessary That the Trucks Pass Down the Ramp in a Relatively Horizontal Position; Hence, the Use of a Simple Retarding-Chain Was Not Possible. The Equipment Shown in This View and in Fig. 21 Accomplished the Desired Result

At all points after the press operation, parts are carried overhead on slat conveyors.

COMBINED TRANSPORTATION AND ASSEMBLY CONVEYORS

Conveyors shown in the layout of Fig. 17 provide both transportation and final assembly. They illustrate the possibility of construction in which a chain runs on edge. There are three separate conveyors; two are located on the floor and carry bodies received from the body plant just described. Each of these lines has a chain length of approximately 2300 ft., with an effective carrying length of about 1800 ft. Trim and assembly operations are performed as bodies pass along the line. Fig. 18 illustrates one of these operations on the conveyor. The third conveyor-line runs overhead; it serves mainly for storage, but is also for the transportation of bodies received complete from outside sources. The conveyor chain used is heavy 6-in. pitch forged chain equipped with hinged pusher-dogs and carrying shoes bolted into the chain links. At the turns, it is guided by rollers mounted in castings set close together to produce nearly a true arc at the turn. The chain runs between two angles which also serve to guide the steel paint-stick upon which the body is mounted. At the drive-sprocket the chain has a 180-deg. wrap, and then drops through the floor to a counter-weighted take-up to care for accumulated slack. The return chain to this point where the load is picked-up is carried on the ceiling of the floor below. This type of construction frequently will make possible the solution of an awkward problem. It should be noted, however, that a chain running flat can be offset without difficulty if the radius of curvature is great enough. An instance of this is shown in Fig. 19. In this case the body assembly-line starts in an old building and ends in a later addition, the column centers of the two being out of line. To effect clearance and working space, it was necessary to offset the chain about 8 ft. as shown. No difficulty was encountered in doing this, nor is any special hold-down device required; the chain simply runs free in a channel section.

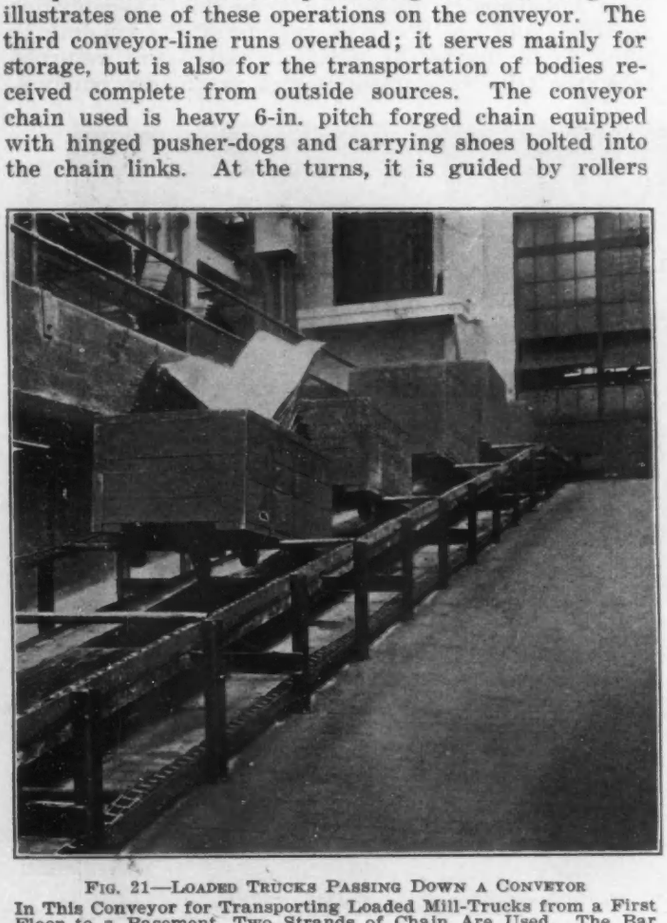


FIG. 21—LOADED TRUCKS PASSING DOWN A CONVEYOR
In This Conveyor for Transporting Loaded Mill-Trucks from a First Floor to a Basement, Two Strands of Chain Are Used. The Bar Between the Chains Picks-Up the Front End of the Truck Just Back of the Front Swivel-Wheels, the Height of the Chain Track on the Slope Being Arranged To Maintain the Required Horizontal Position of the Truck Bed. At the Bottom of the Ramp, the Carrying Bars Pass Through a Narrow Slot and the Trucks Run Off by Gravity Clear of the Following Trucks

The problem of bringing panel and other stampings from the press-room to a shipping dock, as illustrated by the diagram in Fig. 20, presented considerable difficulty. In this instance, all pieces were loaded on mill-trucks in the press-room and had to be carried down a rather steep ramp to the shipping platform where they were pushed with their load onto motor-trucks for shipment. The height of load made it necessary that the mill-trucks pass down the ramp in a relatively horizontal position, so that the use of a simple retarding-chain was not possible. A satisfactory solution was obtained by using the equipment shown. It consists of two strands of chain with a bar between which picks up the front end of the truck just back of the front swivel-wheels, the height of the chain track on the slope being arranged to maintain the required horizontal position of the truck bed. At the bottom of the ramp, the carrying bars pass through a narrow slot and the trucks run off by gravity clear of the following trucks. This equipment required considerably less space, and the initial and operating costs were lower than elevators of equivalent capacity. Fig. 21 is a view near the bottom of the ramp, showing loaded trucks as they pass down the conveyor.

ADVANTAGES OF CONVEYOR SYSTEMS

The actual dollars-and-cents savings produced by these various installations cannot always be determined. The indirect returns in improved conditions, increased production and the like often may be even greater than the direct labor saved. In general, however, the return obtained from investment in mechanical handling-equipment is surprisingly large. A recent conversation with

a plant engineer disclosed the fact that a conveyor installation costing more than $80,000 had fully paid for itself in less than 6 months of operation and was at that time saving about $800 per day, this being a return of about 300 per cent annually on the initial capital-expenditure. Such returns are by no means uncommon. One sub-assembly conveyor costing about $2,000 as installed effected a saving, in direct labor alone, sufficient to pay for itself in the first 2 weeks of its operation.

These illustrations of applications of mechanical handling by no means fully cover the field, but we hope that they afford a broader view of the possibilities of mechanical handling and indicate some clue to the possible solution of individual problems. Mechanical handling-apparatus is being constantly broadened in scope by new methods and new designs, and it is safe to say that rational and profitable solutions to individual problems can be found.

DISCUSSION OF PAPERS AT ANNUAL MEETING

(*Concluded from p.* 398)

as small as 1 sq. cm., and let us further consider an annular ring of, say, 1-cm. annular thickness, with the 1 sq. cm. as the core. If a current, i, flows through this ring for a time, t, the energy converted into heat, will be Ri^2t, or RiQ, where Q is the quantity of electricity flowing through the annulus. Putting $i = 10^5$ and $Q = 0.3$ coulomb, we find that the heat generated is $0.3 \times 10^5 \times 0.24\,R$ calories. This is sufficient to heat up and to melt about 300 R grams of aluminum. It would therefore seem that, since R would be very small for this ring, it would not be heated to nearly the melting-point. Annular rings of successively greater and greater radii would suffer successively less and less on account of both their larger amounts of material and their smaller resistances. Again, if the region of entry were increased to something more than 1 sq. cm., as would seem reasonable, the drasticness of the effect would be reduced. If we should take the potential of the cloud as 10^9 volts and should keep the current the same, the above figures would be increased by a factor of 10. If we should increase the current by a factor of 10 also, the heat generated would be increased by a factor of 100. Even then, it would appear that, in view of the fact that we have everywhere dealt with upper limits, the heating could hardly ever be very drastic, a conclusion which agrees with the opinion expressed by Dr. Millikan.

A much more serious situation would arise if a flash were to strike to ground through the airship, the latter tending to promote this situation by acting as a "weak spot" in the insulation of the path, in virtue of its concentration of the field, particularly at its pointed ends. In this case, the whole cloud might discharge through the balloon. Humphreys[19] quotes times of the order of 0.01 sec. for the duration of the discharge, so that, for such a case, the generation of heat would be 3000 times that calculated above for the case in which the cloud discharged to, but not through, the airship. The sort of initial damage, that is, damage, apart from the explosion of the hydrogen, that I should therefore expect in a metallic airship would be two holes of more or less limited size.

G. S. FULCHER[20]:—After a careful study of various cases in which hydrogen-containing balloons and airships had been destroyed by fire of apparently electrical origin, I came to the conclusion 6 years ago that the danger could not be eliminated unless the surface of the airship were made electrically conducting. Mr. Upson has done this more effectively than I believed possible at that time. With the Metalclad airship, there is no danger due to induced charges from lightning, because the energy is dissipated over too large a surface; the only unavoidable danger is the negligible chance that the ship might happen to lie directly in the path of a lightning discharge. If the danger zone around the valve, where an explosive mixture of hydrogen and air is formed during valving, is protected, as can readily be done, and if obvious precautions are taken in filling the airship with hydrogen, I am convinced that hydrogen can be used with such safety as to make unwarranted the use of helium, except possibly in time of war.

D. F. MINER[21]:—One advantage of using all-metal construction is that any electrical charge taken on by the structure is distributed over the surface and immediately equalized. The electrostatic field inside the container is, of course, zero and there is no chance for ignition of materials inside the envelope.

If the Metalclad airship passes through a cloud and assumes a certain potential due to its charge, and then passes to another cloud of different potential, an equalization must, of course, take place. The airship, being a perfect conductor throughout, should dissipate its charge readily from points of greatest potential gradient, such as sharp edges, fins and structural details. This would take place before it had reached a cloud of different potential. The cloud, on the other hand, does not have the same advantage, because the charges on individual raindrops cannot become discharged on account of lack of conduction.

If the airship should happen to be in the path of a direct lightning-stroke, the resulting damage would, of course, depend on the energy of the discharge. Due to the steepness of wave front, the discharge would tend to spread out over the surface because of the phenomenon known as "skin effect." This would probably result in no very great burning at any part of the structure.

From these considerations, I feel that the Metalclad airship will have advantages from an electrical standpoint.

The developing of the Metalclad airship is a most interesting and promising one, and I heartily congratulate Mr. Upson and his co-workers on having so successfully overcome the many technical and practical difficulties involved.

[19] See Physics of the Air, p. 397.

[20] Corning Glass Works, Corning, N. Y.

[21] Material and process engineering department, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Gear-Steels and the Production of Automobile Gears

By JOHN BETHUNE[1] AND W. G. HILDORF[1]

PRODUCTION MEETING PAPER *Illustrated with* PHOTOGRAPHS

ABSTRACT

STATING that the production of satisfactory gears is one of the most serious problems confronting the automobile builder, the authors give an outline of the practice of producing gears that is used by the company they represent and outline a new method for cutting the rear-axle drive-pinion by using two machines, each machine cutting one side of the teeth. Explanations are given of the various steps in the process and the reasons for stating that this method is not only cheaper but produces gears of higher quality. Numerous suggestions are made for improving gears and axles, and the claim is made that it is doubtful if the spiral-bevel gear has had a fair chance because axles usually have not been designed so that the main consideration was the requirements of the gears.

The results of a number of experiments with transmission-gears seem to indicate that, to get the greatest degree of quietness, every effort should be made to increase the number of teeth in contact and to improve the profile and the tooth spacing. Various kinds of gear-steel are discussed, together with heat-treatments which have given good results. Research work, undertaken to explain variations in machining, in physical properties and in service that cannot be accounted for by chemical analysis or the microscope, has shown a variation in the steel itself which has been found by fracturing samples from the bars after heat-treatment and by a study of the grain size of the steel.

THE production of satisfactory gears is one of the most serious problems confronting the automobile builder today. The choice of a gear-steel and its heat-treatment is closely allied to this production problem. We believe that some very radical changes are going to be made in automobile gearing during the next few years and that a frank interchange of ideas will hasten the time when a more satisfactory system of gearing will be developed. An outline is presented herewith of the practice used by our company in making gears, including gear-steels, their heat-treatment, experiments which we have conducted with gears, recent research-work on steel, and our ideas as to the lines along which research work should be carried on in the future.

PRODUCTION OF REAR-AXLE GEARS

The production of rear-axle gears is treated first and, since the different operations in turning the gear and the pinion are conventional ones, no time will be spent in reviewing them. The gear and the pinion teeth are roughed or gashed in the usual way on Gleason gear-and-pinion roughers, and care is taken to rough slightly deeper than the full depth and to use a roughing-cutter of the same diameter as the finishing-cutter; that is, if the teeth are to be finished with a 9-in. cutter they must be roughed with a 9-in. cutter. The gears are finished by the spread-blade method, which we believe is the usual practice in most factories.

The pinion is not finished in the usual way, which is by chucking it in the generating-machine, dividing the stock and finishing one side of the tooth, then changing the vertical head-setting, giving the pinion a "set over," and finishing the other side of the tooth, thus completing the pinion before removing it from the machine. The new method is, after the teeth are roughed, to put the pinions into a fixture mounted on a small milling-machine and to cut a 3/16-in. keyway in the stem. This fixture has a plunger which enters a tooth space, so the keyway is cut in a definite relation to the teeth. The finishing generating-machines are operated in pairs. One has a cutter with all the cutting edges of the blades on the outside, while the other has a cutter with all the cutting edges of the blades on the inside. The pinion is put into one generating-machine, locating from the keyway, and one side of the teeth is finished. It is then removed and placed in the other generating-machine, which finishes the other side of the teeth. We have called this the duplex method and consider it superior to the old method, for both production and quality. Some of its advantages are discussed in the following paragraphs.

Twice as many blades are in action at any one time; for example, with a 12-in. cutter 20 blades pass by the tooth in the same time that 10 blades would pass by with the old method, using the same feed and cutter speed. The time to finish a tooth can be reduced very materially, and the profile improved at the same time. The reduction in time to produce a pinion will vary from 10 to 25 per cent, according to conditions. The tooth profile can be changed on either the drive side or the reverse side at will, without interfering with the other side. It is often desirable to "flank" or "top" the drive side so as to get a better running position without disturbing the reverse side. It can be done easily by this method and a tooth produced that has better balance. Sometimes it has been found desirable to cut the drive side with one ratio of roll and to cut the reverse side with a slightly different ratio.

One of the objections to the use of the 9-in. cutter has been that it produced too short a lengthwise bearing. With the old method of cutting, nothing could be done to correct this; but, with the duplex method, the radii of the blades can be changed at will and any desired length of bearing produced. Therefore, the advantages of the 12-in. cutter can be combined with those of the 9-in. cutter. Due to the fact that all blades are on one side they can be made wider at the point, which adds materially to the life of the cutter. With the old method the operator had to make two very accurate dial adjustments for each pinion and, often, mistakes were made in the reading of the dial. With the duplex method, these adjustments are eliminated, the only thing required of the operator is to put the pinion into the machine and remove it after the teeth are cut on one side. The two chuckings which are necessary with the duplex method take about 25 per cent less time than the

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one chucking plus the time taken to divide the stock and make the "set over" by the old method.

We are now experimenting to see what can be done by cutting the gear in the same way, but this work has not been carried far enough for us to draw any definite conclusions at present.

FIG. 1—FRACTURE TEST OF A SAMPLE 9 IN. LONG FROM THE ROLLED BAR

For Example, If the Sample Is S.A.E. No. 3140 Steel, It Is Heated to 1550 Deg. Fahr., Held at Heat 1½ Hr. and Cooled in the Air. Then It Is Heated to 1425 Deg. Fahr. and Cooled in the Furnace. The Sample Bars Are Notched by Sawing about One-Third Through at the Center. They Are Broken by Supporting Them at Each End, with the Notch Downward, and Slowly Applying a Load at the Center. The Desired Fracture Is "Silky Fibrous" as Illustrated

FIG. 2—FRACTURE SHOWING A CRYSTALLINE STRUCTURE

A Bar Having This Kind of Fracture Is Very Brittle. In Most Cases the Regular Heat-Treatments Will Not Change This Material So That It Will Break "Tough"

CHAMFERING, TESTING, BURNISHING, AND LAPPING

As to the chamfering of ring-gear teeth, after the gear-teeth are roughed they are chamfered on the large end or outside of the gear. A vertical hobbing-machine having a special hob is used for this purpose. We consider it better to do the chamfering before the teeth are finished because, otherwise, it might raise a burr on the tooth profile.

In testing the gear and pinion for bearing, the gears and pinions are run in a bevel-gear testing-machine to

FIG. 3—FRACTURES OF FIVE SAMPLES FROM THE SAME BAR, EACH HAVING A DIFFERENT HEAT-TREATMENT

The Sample Shown in the Upper Left View Was Heated to 1550 Deg. Fahr. and Cooled in the Furnace. The Fracture Was Crystalline. In the Upper Central View the Sample Was Heated to 1550 Deg. Fahr., Cooled in the Furnace, Reheated to 1520 Deg. Fahr., Quenched in Oil, and Drawn at 900 Deg. Fahr. The Fracture Was Crystalline. For the Sample Illustrated in the Upper Right View, the Treatment Was To Heat to 1600 Deg. Fahr., Quench in Oil, Reheat to 1475 Deg. Fahr., and Cool in the Furnace. The Fracture Was Crystalline. In the Lower Left View, the Sample Was Heated to 1600 Deg. Fahr., Quenched in Oil, Reheated to 1475 Deg. Fahr., Cooled in the Furnace, Reheated to 1520 Deg. Fahr., Quenched in Oil, and Drawn at 900 Deg. Fahr. The Fracture Was Crystalline. The Sample Illustrated at the Lower Right Was Heated to 1800 Deg. Fahr., Quenched in Oil, Reheated to 1475 Deg. Fahr., Quenched in Oil, Reheated to 1475 Deg. Fahr., and Cooled in the Furnace. The Fracture Was "Silky Fibrous." Any One of the Treatments Should Have Caused the Samples To Break with a "Tough" Fracture, but No Treatment Accomplished This Result until a Sample Had Been Heated to More Than 1800 Deg. Fahr. and Quenched from That Temperature

FIG. 4—FRACTURE SHOWING "REEDY" OR "WOODY" STRUCTURE
The Fracture Illustrated Is Very Common and Indicates a Variation in Strength at the Different Parts of the Cross-Section

determine whether they have the correct lengthwise and profile bearing and that they run on the correct center-distance. Corrections are made in the usual way, except that with the duplex method we can change the running position of one side of the tooth without disturbing the other side.

The pinions are burnished in a burnishing-machine without any oscillating movement of the pinion. A light tension is used and the gear is raised and lowered continuously during the burnishing operation so that all parts of the tooth come into contact. The gears are then

FIG. 5—FRACTURE SHOWING A "PIPE"
Many Variations from the Fractures Shown in Figs. 1 to 5 Will Be Found. The Most Dangerous Are the Crystalline and the Very "Reedy" or "Woody" Fractures

heat-treated. The pinion and gear are ground after heat-treatment, the gear being ground on the back and in the bore. When grinding the bore, the gear is trued-up by the bore with an indicator mounted on a special holder.

After hardening, the gears are put into a testing-machine in pairs, and then are lapped on a lapping-machine. They are mounted with the usual backlash and run for a very short time using No. 120 alundum in oil for an abrasive. The gear is raised and lowered continuously so as to bring every part of the pinion-tooth into contact. When the operation is complete, the gears are put into a testing-machine and are checked again for tooth-bearing and sound. This is the final test of the gears before they go into axles. The best gears are sent to repair stock, while the balance go to the axle assembly-line to be built into axles. The gears are adjusted and given a final test for tooth-bearing and sound in the finished axle.

SUGGESTED IMPROVEMENTS IN GEARS AND AXLES

Following are some of the most desirable features which we believe should be incorporated in rear-axles and in gear construction. Some of these opinions are

FIG. 6—FRACTURE SHOWING A LARGE "FLAKE"
Fractures Such as This Were Very Common during the War, but They Are Very Rare Today

radical and many will not agree with us, but gear men live on disagreements.

The pinion should be straddle-mounted. With this mounting there is less tendency for the pinion to tip up

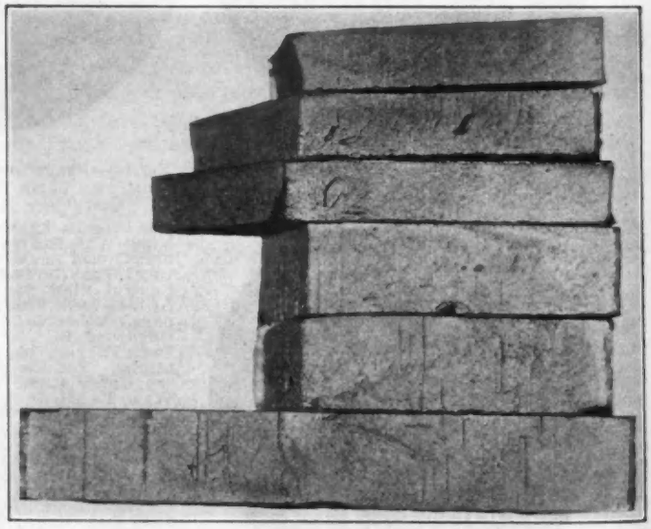

FIG. 7—FRACTURED PARTS OF HARDENED DISCS
The Discs Are Supported around Their Outer Periphery, a Ball Is Placed at the Center and Load Is Applied Until the Disc Breaks. Inclusions of Dirt Are Evident. This Is a More Satisfactory Method Than That of Microscopic Examination, Because There Can Be No Argument as to the Actual Presence of Inclusions

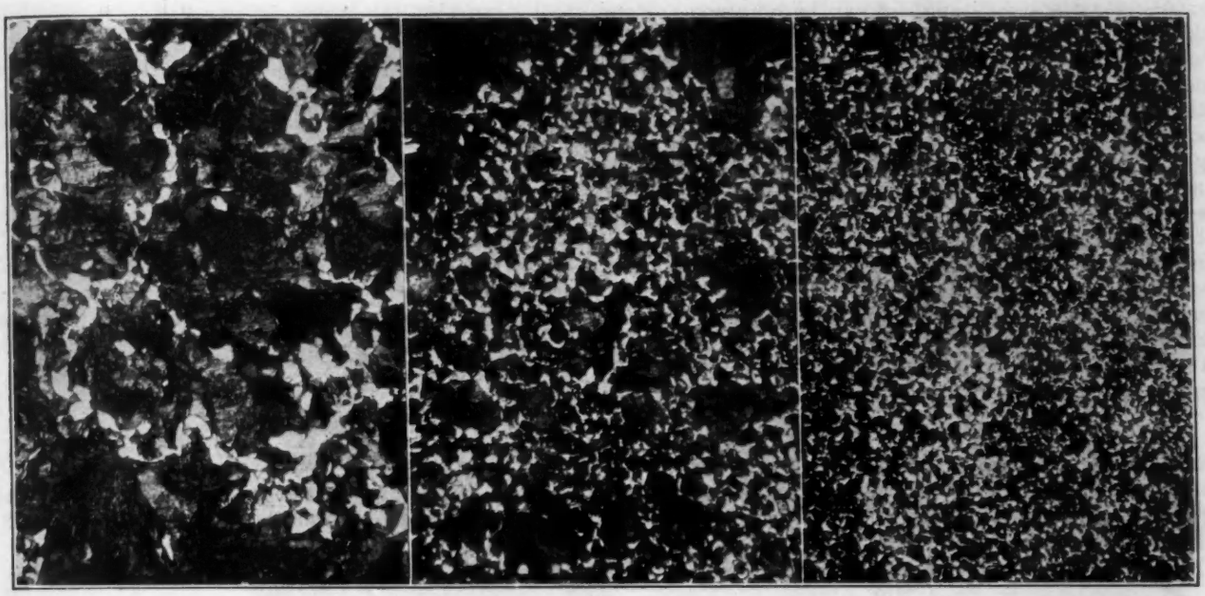

FIG. 8—GRAIN SIZE OF S.A.E. No. 3140 STEEL
From Left to Right, the Views Show a Large Grain, a Medium Grain and a Small Grain. The Samples Were Taken from Different Heats, but Were Treated Exactly Alike and at the Same Time

and throw the bearing to the large end of the teeth, which is very destructive to them. The gears can be cut with the lengthwise bearing nearly in the center of the tooth, which, in spiral-bevel gears, is the only place that the pressure angle of the pinion bears the correct relation to the pressure angle of the gear. With both bearings back of the pinion, it is necessary to cut the gears with the tooth-bearing more or less on the small end of the teeth. The amount varies decidedly in different axles and sometimes in the same axle with different bearing-adjustments. We have known of cases in which it was necessary to have a tooth-bearing for only $\frac{3}{8}$ in. on the small end of the tooth to prevent it from going to the large end under load and destroying the teeth.

The gears should be cut with a 9-in. cutter because the paths of the blades then more nearly intersect the apex of the gear and give less of the skew-gear effect than with a 12-in. cutter. The pinion should be cut by the duplex method and the radii of the blades changed so as to give as long a lengthwise bearing as if it had been cut with a 12-in. cutter.

If hypoid-gears are used, the overhang of the pinion from its bearing is more than with the regular spiral-bevel gears and the straddle-mounting becomes still more desirable. The usual objection to this method of mounting the pinion is the difficulty of getting in a satisfactory bearing with the limited space available in front of the pinion. This can be overcome by mounting the gear on the other side of the differential. With the differential out of the way, plenty of room is available to get a satisfactory bearing in front of the pinion even with a hypoid-gear. With the differential in this position, a

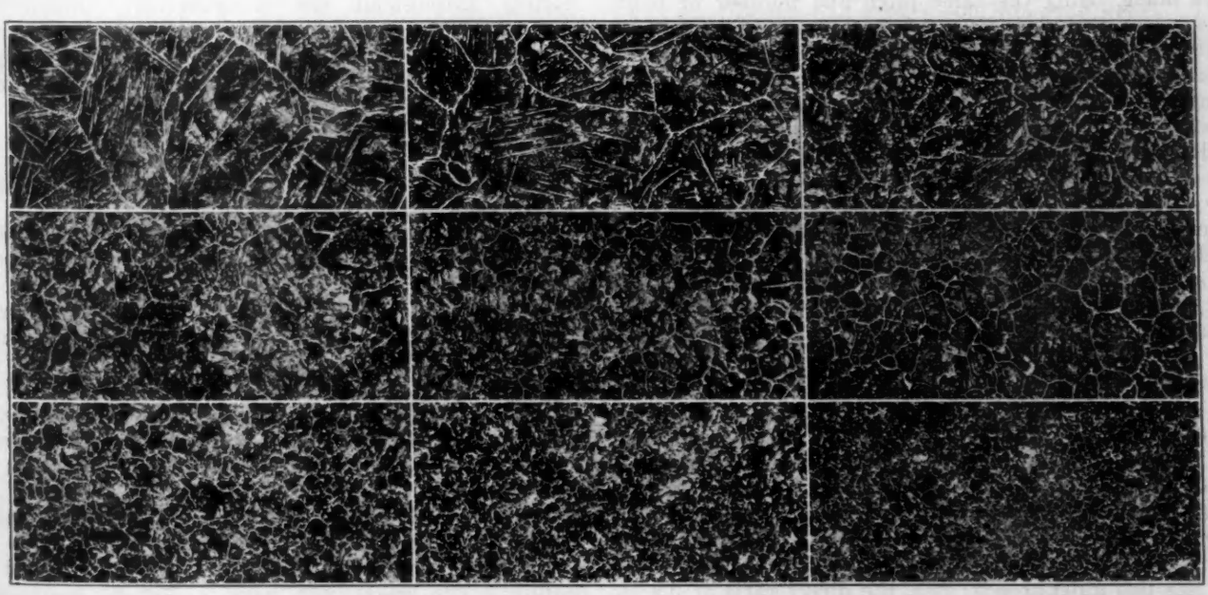

FIG. 9—CHART FOR JUDGING GRAIN SIZE OF STEELS
Early in This Research Work It Became Necessary To Have Standards by Which To Judge the Various Grain Sizes, and This Led to the Development of the Chart Shown

much more satisfactory support can be obtained for the back of the gear. A differential larger in diameter could be used which, in turn, would make the use of a one-piece two-pinion differential possible in many cases. Off-setting the differential would of course throw the housing off-center and the axle-shafts would be of different lengths; however, the advantages gained would more than make up for the inconvenience of two lengths of axle-shafts.

It is doubtful if the spiral-bevel gear has had a fair chance uptodate. It has been condemned in many cases when the gear was not at fault, where conditions surrounding it were such that it could not give satisfactory service. In other words, an axle should be designed so that the main consideration is the requirements of the gears rather than the standard or conventional practice.

Transmission-Gears

Considerable experimenting has been done with the passenger-car gears in an attempt to attain a greater degree of quietness. Various experimental sets of gears were made, using the same pitch and number of teeth. These sets included different pressure angles, various addendums and dedendums and various center-distances. A large number of experiments were also carried out using ground gears. In no case was the degree of quietness under load any better than with the standard 20-deg. full-depth teeth. A decided decrease in sound was obtained by the use of gears of finer pitch. Just how far this decrease in pitch can be carried and what degree of quietness can be obtained without decreasing the life of the transmission has not been determined.

As our experiments progress, it becomes very evident that, to get the greatest degree of quietness, every effort should be made to increase the number of teeth in contact and to improve the profile and the tooth spacing. Driving conditions are now demanding two quiet-speeds and it is going to be up to the engineers and the gear makers to produce them.

Mr. Bethune has equipped his own car with a two-speed axle in which internal gears are used for the second speed. The pinion which does all the driving when the second speed is in use has 17 teeth, of 10/12 pitch. It runs into an internal gear of 22 teeth. This axle has two quiet-speeds; one, the direct ratio of 3.9 to 1.0 and the other, through the internal gears, of 5.8 to 1.0. The car weighed 3600 lb. and was driven 19,000 miles, part of the time with a passenger-and-equipment load that brought the total weight up to 4200 lb. Considerable hilly country was covered during the test; one of the hills encountered was a 17-per cent grade. These figures are given merely for the purpose of showing what gears can do under some conditions.

Selection of Gear-Steel

The selection of a proper gear-steel is difficult because there are so many variable factors such as loads, ratios, pitch, long or stub-teeth, and whether the gears are to be used in a passenger-car, a truck or a motor-coach. The three following oil-hardening steels are generally used: S.A.E. No. 3250, 5150 and 6150. Of the carburizing steels S.A.E. No. 2315 and 2512 are often used, the former being a favorite for use in ring gears and pinions.

Forging and Preliminary Heat-Treatments

When gears are heated for forging they should be heated slowly enough so that they will be heated uniformly throughout the cross-section. Optical pyrometers are very useful in determining forging temperatures. Whenever possible we upset our gear forgings, to obtain uniform strength in the teeth and to eliminate warpage.

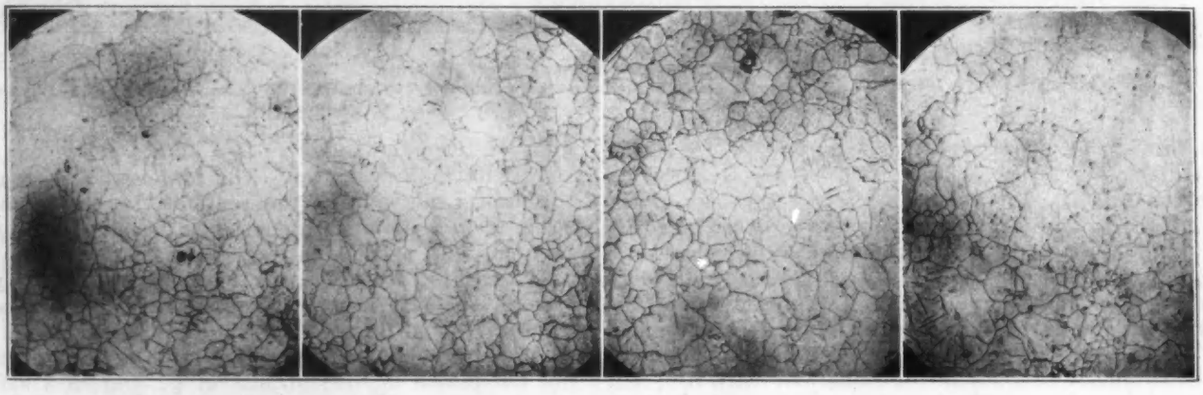

Fig. 10—Grain Sizes of Samples from No. 1 Bar, Magnified Approximately 36 Times
In Each Case, the Etching Was Done by Hot Sodium Picrate. The Sample at the Left Was Heated to 1850 Deg. Fahr. and Furnace-Cooled. In the Left Central View, the Sample Was Heated to 1520 Deg. Fahr., Held at Heat ½ Hr., Quenched in Oil, and Drawn at 900 Deg. Fahr. for 1 Hr. Then It Was Heated to 1850 Deg. Fahr. and Furnace-Cooled. The Sample Shown in the Right Central View Was Heated to 1550 Deg. Fahr., Held at Heat 1½ Hr. and Furnace-Cooled. Then It Was Heated to 1850 Deg. Fahr. and Furnace-Cooled. The Treatment for the Sample Shown at the Right Was To Forge at 1950 Deg. Fahr., Reheat to 1850 Deg. Fahr. and Furnace-Cool

With the oil-hardening steels already mentioned, heating to 1550 to 1575 deg. fahr. or, for S.A.E. No. 6150 steel, perhaps to a slightly higher temperature, quenching in oil and then drawing at 1350 to 1375 deg. fahr. will give a Brinell hardness under 217 and a structure which will machine fairly well and leave the gears in a condition such that they will go through the final heat-treatment with practically no warpage. However, the general treatment is an annealing, rather than a quench-and-draw treatment. Its advocates claim that it gives much better machining results. Heating to 1525 to 1550 deg. fahr. and holding at heat long enough to have all the gears thoroughly heated through and then cooling under 50 deg. fahr. per hr. is claimed to have given very good results.

In regard to carburizing steels, a very satisfactory treatment for S.A.E. No. 2315 steel is to heat to 1550 deg. fahr., holding the gears at heat 1½ hr. and air-cooling. The gears will have a Brinell hardness of about 179.

Machining results are often variable, even though the

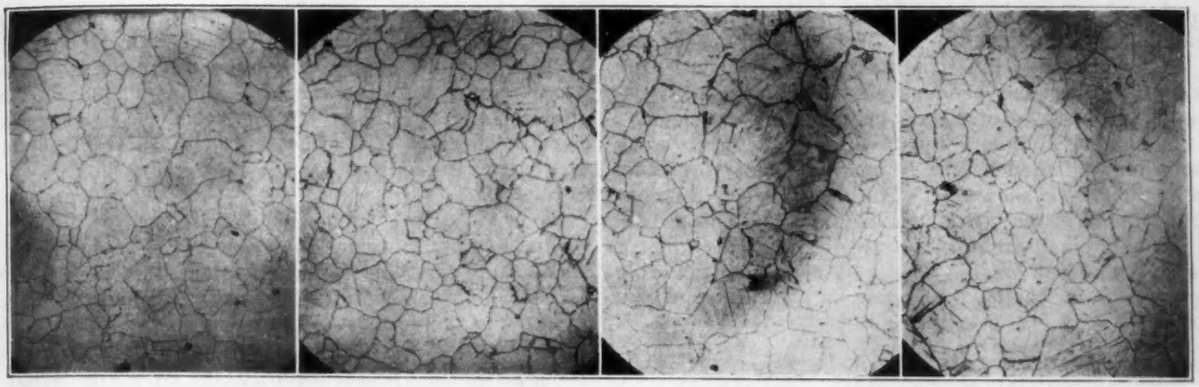

FIG. 11—GRAIN SIZES OF SAMPLES FROM NO. 5 BAR, MAGNIFIED APPROXIMATELY 36 TIMES

In Each Case, the Etching Was Done by Hot Sodium Picrate. The Sample at the Left Was Heated to 1850 Deg. Fahr. and Furnace-Cooled. In the Left Central View, the Sample Was Heated to 1520 Deg. Fahr., Held at Heat 1½ Hr., Quenched in Oil, and Drawn at 900 Deg. Fahr. for 1 Hr. Then It Was Heated to 1850 Deg. Fahr. and Furnace-Cooled. The Sample Shown in the Right Central View Was Heated to 1550 Deg. Fahr., Held at Heat 1½ Hr. and Furnace-Cooled. Then It Was Reheated to 1850 Deg. Fahr. and Furnace-Cooled. The Treatment for the Sample Shown at the Right Was To Forge at 1950 Deg. Fahr., Reheat to 1850 Deg. Fahr. and Furnace-Cool

Brinell hardnesses and structures are identical; this statement is amplified in the latter part of the paper.

FINAL HEAT-TREATMENTS

In reference to oil-hardening steels, there seems to be considerable controversy in regard to electric-furnace-treated versus cyanide or salt-bath-treated gears. We believe it is safe to say that the cyanide-treated gears will wear much better, will be somewhat noisier and have a different sound than the electric-furnace-treated gears.

Concerning the carburizing steels, very good results can be obtained from S.A.E. No. 2315 steel by quenching it in oil from 1460 deg. fahr. This treatment seems to give the highest impact-value possible with this steel. The single treatment is also an advantage in that the gears do not warp so much as if a double treatment had been given. Our ring gears made from this steel are heated in a continuous electric-furnace, which gives very uniform results. One of the important aids in getting these results is an inspection for roundness of the bore and for burrs in the bore and on the back of the gears before they go into the furnace. If the bores are not round, the normalizing treatment has not been effective and, if burrs had been allowed to remain in the bore or on the back, they would have aided in causing warpage.

WARPAGE

Some of the more important precautions which are generally taken in an attempt to overcome warpage are as follows: Wherever the shape of the gear permits, the forgings should be upset. The preliminary treatment should be such that the gear not only will machine well but that it will be in a condition such that it will go through the final treatment with the minimum amount of warpage. The final treatment should be worked out very carefully, paying particular attention to maximum temperature and to rate of heating. The quenching medium and method of quenching are also important; for example, if we use the same temperature and rate of heating and quench one gear in water and one in oil, they very likely will not be of the same size and one will be warped more than the other. Likewise, if one gear is quenched by a method which has given minimum warpage and another gear is carelessly quenched, the latter gear will be warped more than the former.

The normality of steel also has its effect upon warpage. For example, we once had a heat of abnormal S.A.E. No. 2315 steel which had been made into ring gears. These gears warped badly. To aid in proving that the cause was in the steel itself, 25 ring gears were kept until con-

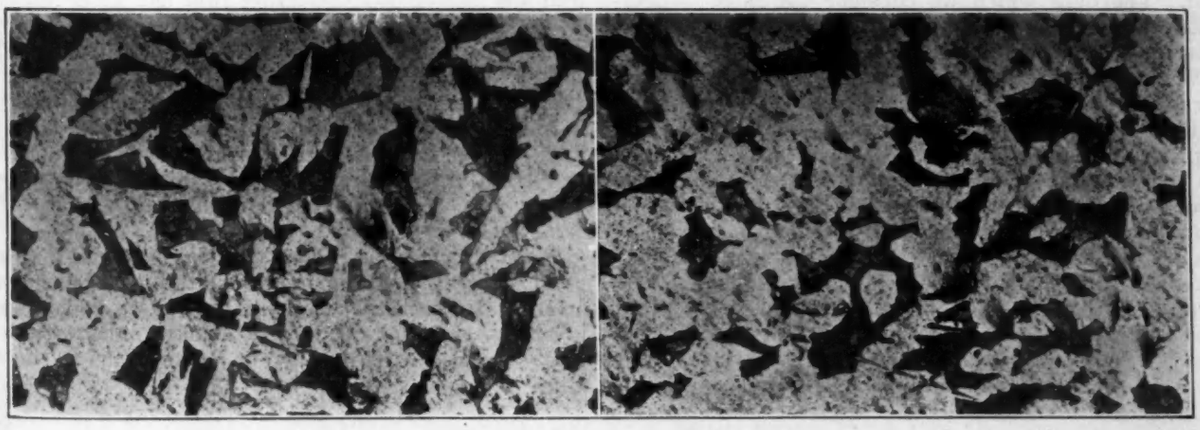

FIG. 12—GRAIN SIZES OF SAMPLES FROM A BAR OF NORMAL S. A.E. NO. 1015 STEEL, MAGNIFIED 100 TIMES

In the View at the Left, the Sample Was Heated to 1850 Deg. Fahr. and Furnace-Cooled. The Sample Shown at the Right Was from the Same Bar. It Was Heated to 1700 Deg. Fahr. for 36 Hr. and Slow-Cooled. Then It Was Reheated to 1850 Deg. Fahr. and Furnace-Cooled. The Etching Was Done by a 2-Per Cent Nitric-Acid Solution

ditions were normal and there was no difficulty due to warpage. Then these gears were mixed with others and sent to the heat-treating department without notifying anyone that they had been saved. The inspection department scrapped 24 of the 25 gears due to warpage.

A much more complete report of this research work will soon be published by the American Society for Steel Treating in its *Transactions*. The main reason for conducting this research work was to find the reasons for variations in machining, in physical properties and in service. Variations existed which we have not been able to account for by chemical analysis or by the use of the microscope.

Fracture Testing of Steel

The fracture test consists of taking samples about 9 in. long from the rolled bars and, if the steel is S.A.E. No. 3140, heating it to 1550 deg. fahr., holding at heat 1½ hr. and cooling in the air. Then heating to 1425 deg. fahr. and cooling in the furnace. The sample bars are notched by sawing about one-third through at the center. They are broken by supporting the bars at each end, with the notch or saw slot downward, and slowly applying a load at the center. The desired fracture is "silky fibrous" and is shown in Fig. 1. A crystalline fracture is shown in Fig. 2. A bar having this kind of fracture is very brittle. In most cases, the regular heat-treatments will not change this material so that it will break "tough." A good example of this is indicated in Fig. 3, which shows fine fractures of the same bar with different heat-treatments. Any one of the treatments should have caused the samples to break with a tough fracture, but no treatment accomplished this result until a sample had been heated to more than 1800 deg. fahr. and quenched from that temperature. When using such material the fracture of the finished product, after being hardened and drawn, cannot be distinguished in most cases from that of the original bar.

Another very common fracture is shown in Fig. 4. We call this structure "reedy" or "woody." Its fracture indicates a variation in strength at the different parts of the cross-section; for example, "inclusions" will cause a steel to break with this kind of a fracture but does not account for all such conditions. A piped bar is shown in Fig. 5. The next fracture, Fig. 6, shows "flakes" in the steel. They were very common during the war but are very rare today.

Many variations from the above fractures will be found. The ones which we consider the most dangerous are the crystalline and the very "reedy" or "woody" fractures. While we have not as yet positive proof, we believe these two structures are dangerous because they lower the impact and the fatigue properties of the steel, and it is these properties which are causing the most of our service failures.

To determine the amount of inclusions in steel we fracture hardened discs, as shown in Fig. 7. The discs are supported around their outer periphery, a ball is placed at the center and load is applied until the disc breaks. This is much more satisfactory in most cases than an examination under the microscope, because there can be no argument as to whether inclusions are present or not.

We have found that crystalline and fibrous steels do not machine alike even though the Brinell hardness is the same. For example, if an operator is cutting the splines on gears of crystalline steel and a gear of fibrous steel is put into the machine, the splines will be cut undersize if the limits are the same as those generally used for splines. In other words, a different setting of the cutter is required for the fibrous steel.

Grain Size of Steel

The grain size varies to a very great extent from heat to heat of steel, and to a lesser degree in the same heat. It does not seem possible by ordinary heat-treatment to bring grains of different samples to the same size and keep them the same. Some are naturally large and grow readily, while others seem to be naturally small and remain small. Samples of S.A.E. No. 3140 steel are shown in Fig. 8. From left to right these views show a large grain, a medium grain and a small grain. The samples were taken from different heats but were treated exactly alike and at the same time. Early in this work it was necessary to have standards by which to judge the various grain-sizes. With the help of the United Alloy Steel Co., the chart shown in Fig. 9 was developed.

Suppose we choose six bars of steel from different heats and from different kinds of steel and heat-treat them by heating to 1850 deg. fahr., furnace-cool a sample from each bar and note the grain size; then the remainder of each bar be cut into several samples, each to be treated in a different way. Consider that a sample from each bar be quenched in oil and drawn, that another be annealed and that another be forged at 1950 deg. fahr. Also suppose that a sample of S.A.E. No. 1015 steel be heated to 1700 deg. fahr., held at heat for 36 hr. and then slow-cooled, and that all the samples be then heated to 1850 deg. fahr. and furnace-cooled. When the samples are examined under the microscope it will be found that all of them, regardless of heat-treatment or work done on them, have gone back to the same grain-size as was determined at the start of the test; in other words, all the samples of No. 1 bar, of No. 2 bar and so on will have grains of the same size.

The grain size of one of the natural bars is shown at the extreme left in Fig. 10, while the other three views show the heat-treated, the annealed and the forged samples from the same bar after they have all been given the same treatment. The grain size of a different natural bar is shown at the extreme left in Fig. 11, while the other three views show the heat-treated, the annealed and the forged samples from this bar after they have been given the same treatment. The grain size of the sample from the bar of S.A.E. No. 1015 steel is shown at the left in Fig. 12, while the view at the right shows the grain size after it had been heated to 1700 deg. fahr. for 36 hr., slow-cooled and then heated to 1850 deg. fahr. and furnace-cooled. Some variation will be noticed in the grain sizes of the different samples from the same bar, yet it is remarkable how nearly they are of the same size.

From what has been done thus far it seems that large-grained steel is always more brittle than fine-grained steel, that the smaller grained steel has a wider hardening-range and that, if we are to have steel with a naturally small grain, it must be made such at the steel mill.

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Aug. 10 and Sept. 10, 1926. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member.

ALLEN, FRED E. (A) superintendent, Auburn Button Works, Inc., *Auburn, N. Y.;* (mail) 19 North Park Avenue.

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COLE, D. S. (M) research engineer, Leece-Neville Co., 5363 Hamilton Avenue, *Cleveland.*

COREY, C. H. (A) New England manager, C. G. Spring & Bumper Co., New York City; (mail) 1896 Washington Street, *Auburndale, Mass.*

DEAVER, L. A. (M) manager of technical and tire divisions, B. F. Goodrich Co., *Akron, Ohio.*

DE BELL, GEORGE W. (J) stress analyst, Huff-Daland Airplane Co., *Bristol, Pa.;* (mail) Maple Beach.

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DOLE, JOHN L. (A) secretary, Dole Valve Co., 1923 Carroll Avenue, *Chicago.*

FAIREY, CHARLES R. (F M) chairman, Fairey Aviation Co., Ltd., *Hayes, Middlesex, England.*

FAY, E. F. (M) superintendent and partner, Doane Motor Truck Co., 428 Third Street, *San Francisco.*

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HERBERT, HOWARD D. (A) assistant general manager, Lambert Tire & Rubber Co., Springfield Road, *Barberton, Ohio.*

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HERRON, OLLIE L. (A) president, Herron-Zimmers Moulding Co., Inc., 2334 South Michigan Avenue, *Chicago.*

HESSLER, ROBERT V. (A) Eastern sales representative, Brown-Lipe Gear Co., 1117 West Fayette Street, *Syracuse, N. Y.*

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SOUNITZA, W. (A) mechanical engineer, Azneft Government Oil Fields, Bakou, Russia; (mail) 101 Stevenson Avenue, *Pasadena, Cal.*

SPOONER, A. P. (M) engine tests, Bethlehem Steel Co., *Bethlehem, Pa.*

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STRUNK, EDWIN H. (J) student, Packard Motor Car Co., *Detroit.*

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TALLMAN, A. H. (A) president, Tallman Brass & Metal Ltd., *Hamilton, Ont., Canada.*

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Applicants *for* Membership

The applications for membership received between Aug. 14 and Sept. 15, 1926, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ASSOCIATION OF NATURAL GASOLINE MANUFACTURERS, *Tulsa, Okla.*

BOSSARD, J. M., manager, Alvord-Polk Tool Co., *Millersburg, Pa.*

BOWLES, JAMES T. B., petroleum technologist Crown Central Petroleum Corporation, *New York City.*

CORDERY, THOMAS, automotive engineer, Vauxhall Motors, Ltd., *Luton-Beds, England.*

COZETTE, RENE, administrator and chief engineer, Société Anonyme du Carburateur Cozette, *Neuilly-Seine, France.*

DAWSON, CHARLES, assistant technical engineer, Yellow Coach & Cab Co., *Chicago.*

DONNAY, JEAN, civil engineer, Société Automobiles Chenard & Walcker, *Gennevilliers, Seine, France.*

DURHAM, FRED S., vice-president and treasurer, Bonney Forge & Tool Works, *Allentown, Pa.*

FAGAN, THOMAS Z., sales manager, Scintilla Magneto Co., Inc., *Sidney, N. Y.*

FARMER, CHARLES D., superintendent of equipment, State Highway Commission, *Raleigh, N. C.*

GILLMORE, BRIGADIER-GEN. WILLIAM E., chief of supply division, Air Service, *City of Washington.*

HURLIN, HENRY B., inspector and tester, maintenance department, Rolls-Royce of America, Inc., *Springfield, Mass.*

IRELAND, G. S., president, Ireland Aircraft, Inc., *Garden City, N. Y.*

JASPER, ELMER P. chief draftsman Wills Sainte Claire, Inc., *Marysville, Mich.*

JONES, G. LESTER B., mechanical engineer, Sperry Gyroscope Co., *Brooklyn, N. Y.*

KELLER, ADRIAN D., associate in mechanical arts, Southern branch, University of California, *Los Angeles.*

KNOX, GARNER L., engineer, Utility Trailer Mfg. Co., *Los Angeles.*

KOEHLER, ROLAND C., technical engineer, Yellow Truck & Coach Mfg. Co., *Chicago.*

LANDMANN, HERBERT A., assistant marine superintendent, Tice Towing Line, *New York City.*

LEWIS, H. S., vice-president, Parish Mfg. Corporation, *Reading, Pa.*

LINN, ELLERY C., sales agent, Linn Mfg. Corporation, *Morris, N. Y.*

MALTBY, E. D., member of firm and manager, Frank M. Cobbledick Co., *Los Angeles.*

MULLANEY, RICHARD, mechanical engineer, Goodlin Automotive Equipment Co., *South Bend, Ind.*

NICHOLLS, RAYMOND E., engineering draftsman, *Wallingford, Conn.*

NOLLER, CHARLES W., experimental assistant, International Motors Co., *Long Island City, N. Y.*

O'DONOHOE, CORNELIUS M., chief tool designer, Lycoming Mfg. Co., *Williamsport, Pa.*

ONKEY, EDWARD P., tool designer, Remy Electric Co., *Anderson, Ind.*

ORD, MALCOLM L., president, Universal Machinists, Inc., *Denver.*

PARSONS, MAURICE B., wheel engineer, Motor Wheel Corporation, *Lansing, Mich.*

PHILLIPS, ERNEST B., chief chemist, Sinclair Refining Co., *New York City.*

RANDALL, HENRY D., manager of sales, non-metallic gear department, General Electric Co., *Schenectady, N. Y.*

RAYMOND, W. H., manager of automotive division, Armour & Co., *Chicago.*

RICE, WALTER E., mechanical inspector, International Harvester Co., *Springfield, Ohio.*

ROUSTON, WILLARD R., automotive mechanics instructor, Placer Union High School, *Auburn, Cal.*

RYCE, LUCIUS C., *Fitzwilliam Depot, N. H.*

SCHAFER, O. H., gear specialist, Diamond State Fibre Co., *Chicago.*

SCHULTHEIS, HOWARD M., salesman, Charles D. Schmidt Corporation, *New York City.*

SLATTER, ALBERT J., tire designer, Dunlop Tire & Rubber Corporation of America, *Buffalo.*

SMITH, WESLEY L., pilot, Air Mail Service, Hadley Field, *New Brunswick, N. J.*

STEIN, CHARLES F., checker and tool designer, Nash Motors Co., *Kenosha, Wis.*

TOCH, MAXIMILIAN, vice-president, Toch Bros., Inc., New York City; vice-president, Standard Varnish Works, *New York City.*

TOMPKINS, C. S., sales engineer, J. B. Ford Co., *Wyandotte, Mich.*

VOORHIES, CARL, assistant chief inspector, Stutz Motor Car Co. of America, Inc., *Indianapolis.*

WADE, LEIGH, member of the board of directors, W. T. Edwards Mfg. Co., *New London, Conn.*

WARSINSKE, NORMAN GEORGE, chief pilot and manager, Valley Aero Co., *Bakersfield, Cal.*

WELKER, JAMES J., service manager, General Motors Export Co., *New York City.*

WHEELER, WILLIAM H., president, Fedco Number Plate Corporation, *New York City.*